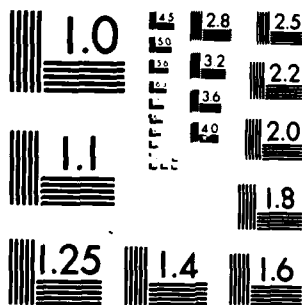


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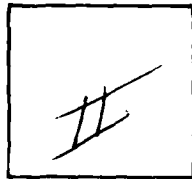
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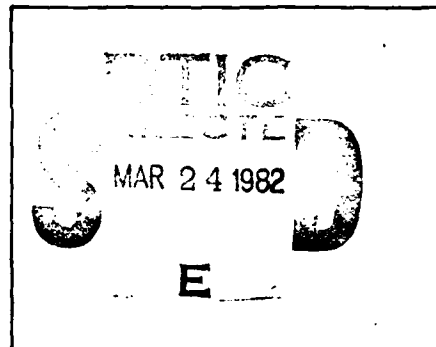
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MX SITING INVESTIGATION
GEOTECHNICAL SUMMARY
PRIME CHARACTERIZATION SITES
CENTRAL HIGH PLAINS
CANDIDATE SITING PROVINCE

Prepared for:

U. S. Department of the Air Force
Space and Missile Systems Organization
(SAMSO)
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

25 September 1978
15 February 1979 (rev.)

PRIME CHARACTERIZATION SITES
CENTRAL HIGH PLAINS CSP

ERRATA

Replace the following figures with revised ones which accompany this sheet: Figures 5 (p. 15), 6 (p. 17), 12 (p. 33), 13 (p. 34), 18 (p. 51), and 19 (p. 52).

Replace the following tables with revised ones which accompany this sheet: Tables 5 (p. 18), 6 (p. 19), 12 (p. 36), 13 (p. 37), 19 (p. 53), and 20 (p. 54).

The following corrections are to be made to the original text:

- * page 1, last paragraph, line 5: Change "...geo environ-mental..." to read "...geo-environmental..."
- * page 6, Section 2.1, line 3: Change "...is..." to read "...are..."
- ✓ page 10, Figure 2: Generalized geologic map base revised, see Figure 5.
- * page 11, paragraph 2, line 5: Change "... (0.13 to 1.3 km) ..." to read "... (0.46 to 0.74 km) ..."
- * page 24, Section 3.1, line 3: Change "...is..." to read "...are..."
- * page 24, Section 3.1, line 4: Change "...informatin..." to read "...information..."
- ✓ page 28, Figure 9: Generalized geologic map base revised, see Figure 12.
- * page 29, line 2: Change "... (1.3 km) ..." to read "... (0.74 km) ..."
- * page 41, Section 4.1, line 3: Change "...is..." to read "...are..."
- ✓ page 45, Figure 15: Generalized geologic map base revised, see Figure 18.

* Corrections have already been made in some report copies.

FOREWORD

This report was prepared for the Department of the Air Force, Space and Missile Systems Organization (SAMSO) in compliance with conditions of Contract No. F04704-77-C-0010, and is a geotechnical summary of the three prime Characterization sites in the Central High Plains Candidate Siting Province (CSP). The three sites are Sterling, Colorado; Scott City, Kansas; and Cimarron, Texas.

The report presents representative data obtained from geotechnical field investigations performed at the three sites as part of the Characterization program. The information obtained from these studies, in combination with data obtained in the Screening studies, has been used for geotechnical ranking (FN-TR-25).

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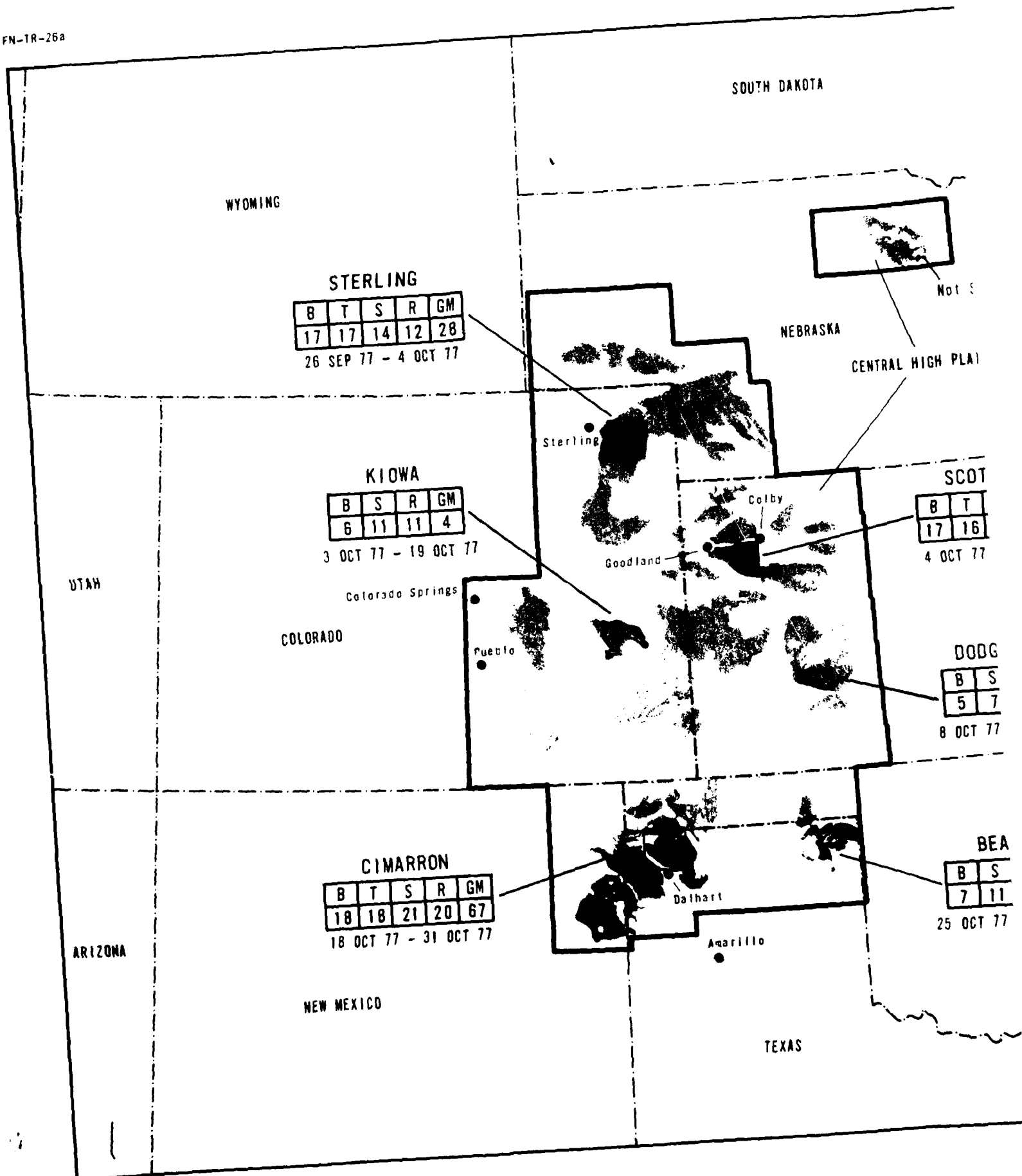
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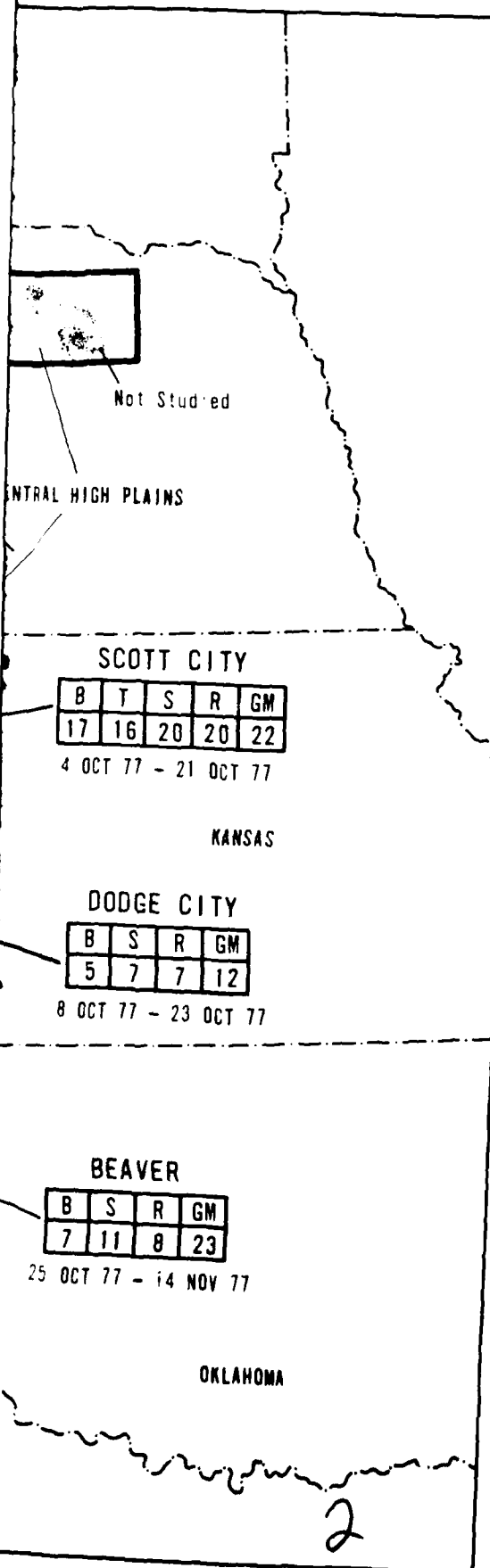
This report presents the results of geotechnical field investigations performed in the Sterling, Scott City, and Cimarron Characterization sites located respectively in northeastern Colorado, west-central Kansas, and the northern panhandle of Texas. Representative data collected and analyzed for these sites are presented. Access to the remaining data can be arranged through SAMSO/MNND, Norton Air Force Base, California.

The three sites are located in the Central High Plains Candidate Siting Province (CSP), one of six provinces included in the geotechnical Characterization studies. The location of the sites within the CSP is shown in Figure 1.

The Central High Plains CSP is characterized by exceptionally flat plains, broad river valleys, and low rolling hills. The CSP lies predominantly within the states of Colorado and Kansas, with portions extending into Nebraska, New Mexico and Texas.

Suitable areas remaining after Intermediate Screening were divided into CSPs based on similar geotechnical characteristics. Intermediate Screening studies (FN-TR-17) indicated that existing data were inadequate for follow-on geotechnical and geo-environmental evaluations, screening, site selection, and ranking studies. Therefore, the Characterization studies were developed to provide a rapid, relatively inexpensive method of gathering geotechnical data in a small area (maximum 700 nm²; 2400 km²) which is considered to be representative of a larger area within the CSP.





EXPLANATION

ACTIVITIES

- B - BORINGS
- T - TRENCHES
- S - SHALLOW SEISMIC REFRACTION LINES
- R - ELECTRICAL CONDUCTIVITY LINES
- GM - GEOLOGIC RECON MAPPING STATIONS

B	T
17	16

 — Activity
 — Quantity of each activity



SUITABLE AREA



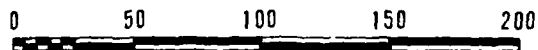
SUITABLE ROCK AREA



PRIME SITE



SUPPLEMENTAL SITE



NAUTICAL MILES



STATUTE MILES



KILOMETERS

CHARACTERIZATION SITES
AND FIELD ACTIVITIES
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
1

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Emphasis was placed on the construction characteristics of the geologic units as they apply to the MX missile basing options. Objectives of the Characterization studies were to obtain data that address the following geotechnical aspects:

- o Surficial geology and terrain
- o Subsurface conditions
- o Geophysical properties
- o Engineering properties

Although the program originally emphasized data collection for the trench and horizontal shelter basing modes, the data were utilized for evaluation of the vertical shelter basing mode as well. Characterization was, therefore, an extension of the screening process whereby the necessary geotechnical information was developed to support the broader MX system design activities that were taking place concurrently and to provide a firmer basis from which to geotechnically rank the remaining suitable area considering different alternative basing modes.

Six Characterization sites (three prime and three supplemental) were selected in the Central High Plains CSP (Figure 1), representing a total investigated area of less than 15 percent of all suitable area within the CSP. The prime sites (Sterling, Scott City, and Cimarron) best represent the known geologic, geomorphic and geo-environmental setting of a portion of the CSP. The Characterization site selection process began with a delineation of geotechnically similar areas within each CSP having analogous depositional and geologic histories, rock and

water depths, and tectonic settings. Once these areas had been identified, non-geotechnical factors were applied to delineate the actual Characterization site boundaries. These non-geotechnical selection factors included access, proximity to support facilities, environmental sensitivities, and local logistical requirements.

To determine the surface and subsurface geotechnical conditions in Sterling, Scott City, and Cimarron, a combination of geologic, geophysical, and soils engineering techniques were used. These include:

- o Analysis of available data
- o Delineation of surficial geologic units from soil groups mapped on U.S. Department of Agriculture, County Soil Survey (SCS) aerial photos
- o Geologic field check of units interpreted from SCS aerial photos and determination of physical properties of the surficial units at selected field stations
- o Shallow seismic refraction and electrical conductivity surveys to obtain subsurface profile information
- o Drilling and trenching to determine subsurface characteristics and obtain soil samples
- o Laboratory testing of soil samples to determine engineering properties

Respective county offices for each site were contacted before initiation of field investigations in order to delineate buried utility lines and to obtain access permits. Also, prior

to initiating any field work, an archeological and environmental inspection was conducted at each site to ensure minimal environmental impact and to avoid damage to archeologic and historic sites. To further minimize potential impacts, all field activities were performed adjacent to existing roads or other previously disturbed areas.

2.0 STERLING SITE

The Sterling Characterization site covers an area of 604 nm² (2075 km²) in northeastern Colorado. Located in the high plains of Colorado, the site is bounded by the South Platte River on the west, sand hills on the east and US Highways 6 and 34 on the north and south, respectively. A network of graded and paved farm roads provides access to all areas within the site.

2.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site are presented in Table 1. Detailed information about the soils engineering field activities (17 borings and 17 trenches) is summarized in Tables 2 and 3. Locations of all the field activities are shown in Figure 2.

2.2 SURFICIAL GEOLOGY AND TERRAIN

The Ogallala Formation is the predominant surficial geologic unit covering approximately 74 percent of the site. The formation has a typical thickness of about 200 feet (61 m) and is chiefly composed of unconsolidated, weakly to strongly cemented sands, silts and gravels. A thin cover of eolian sands and silts covers most of the formation, ranging in thickness from two to ten feet (0.6 to 3 m). Thick loess deposits cover 14 percent of the site, mostly in the southwest corner. Sand dunes, covering six percent of the area, are significant along the eastern boundary. Fluvial, stream terrace, and playa

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological mapping stations	28
Shallow refraction	14
Electrical conductivity	12

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
12	50 (15)
4	100 (30)
1	300 (91)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
15	14 (4)
1	8 (2)
1	3 (1)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	177
Sieve Analysis	34
Hydrometer	20
Atterberg limits	22
Specific gravity	6
Consolidation	2

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	6
Triaxial compression	5
Direct shear	5
Compaction	3
CBR	2
Chemical Analysis	2

SCOPE OF FIELD AND LABORATORY
ACTIVITIES
STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
1

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BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
SG-B-1	99.0 (30.2)	Hollow Stem Auger	D, SS
SG-B-2	51.0 (15.5)	Hollow Stem Auger	D
SG-B-3	52.5 (16.0)	Hollow Stem Auger	D, SS
SG-B-4	101.5 (30.9)	Rotary Wash	P, SS
SG-B-5	52.5 (16.0)	Hollow Stem Auger	D, SS
SG-B-6	301.2 (91.8)	Rotary Wash	P, D, SS
SG-B-7	52.5 (16.0)	Hollow Stem Auger	D, SS
SG-B-8	51.0 (15.5)	Hollow Stem Auger	D, B
SG-B-9	101.9 (31.1)	Rotary Wash	P
SG-B-10	51.0 (15.5)	Hollow Stem Auger	D
SG-B-11	51.0 (15.5)	Hollow Stem Auger	D
SG-B-12	103.5 (31.5)	Rotary Wash	P, SS
SG-B-13	51.0 (15.5)	Hollow Stem Auger	D
SG-B-14	51.0 (15.5)	Hollow Stem Auger	D
SG-B-15	51.0 (15.5)	Hollow Stem Auger	D
SG-B-16	51.5 (15.7)	Rotary Wash	P, SS
SG-B-17	51.0 (15.5)	Hollow Stem Auger	D

P = Pitcher sample (undisturbed)

D = Fugro Drive sample (relatively undisturbed)

B = Bulk sample (disturbed, but representative)

SS = Split Spoon sample (disturbed, but representative)

ENGINEERING FIELD ACTIVITIES - BORINGS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
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TABLE
2

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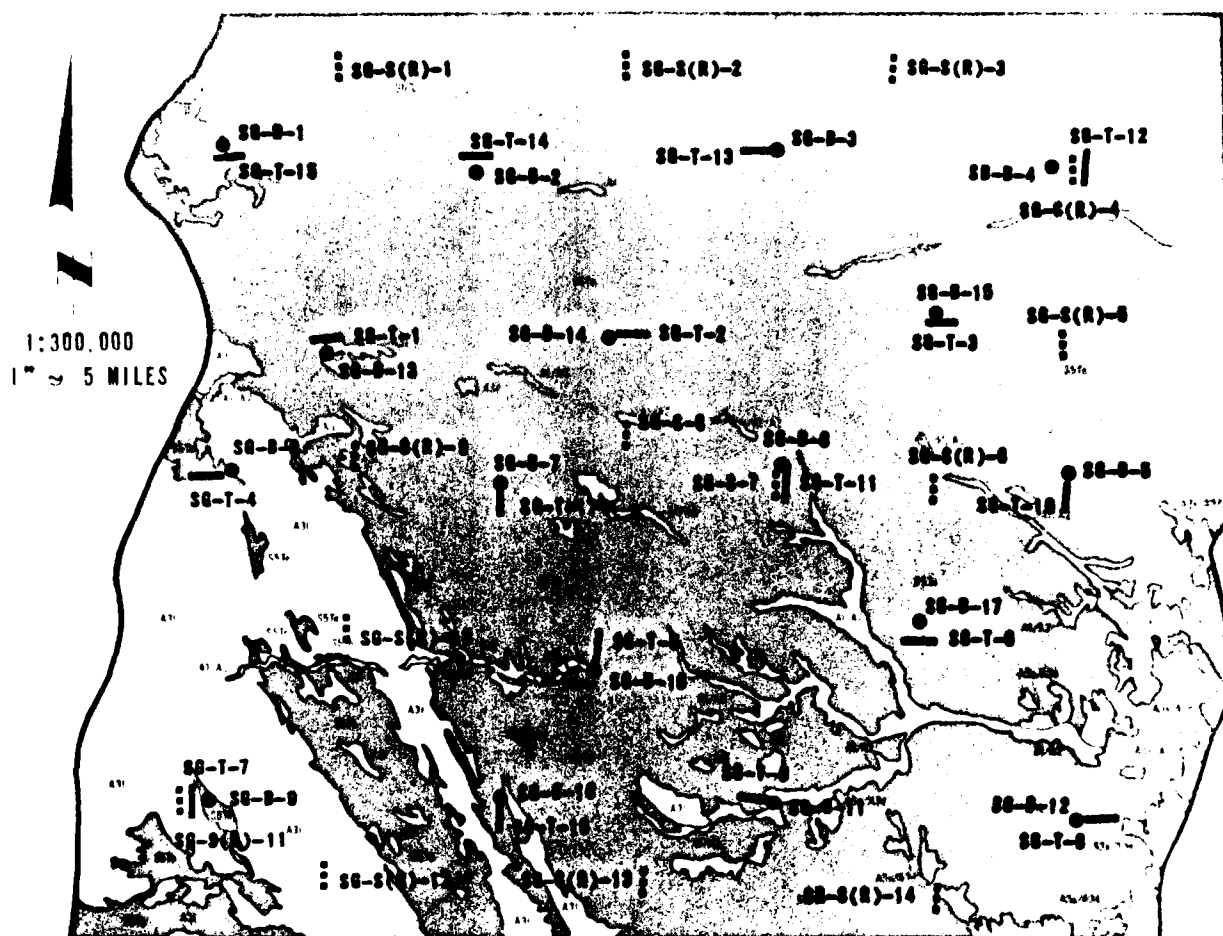
TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
SG-T-1	14.0 (4.3)	Stable, stage I caliche 5-7' (1.5-2.1m)
SG-T-2	14.4 (4.4)	Stable, stage I caliche 1.5-2.5' (0.5-0.8m)
SG-T-3	14.0 (4.3)	Stable, stage III caliche 1-2' (0.3-0.6m) and 3.5-5' (1.1-1.5m)
SG-T-4	13.5 (4.1)	Stable, stage II caliche 9.5-13.5 (2.9-4.1m)
SG-T-5	15.0 (4.6)	Stable, stage I caliche 6-8' (1.8-2.4m)
SG-T-6	14.4 (4.4)	Stable, stage I caliche 14.1-14.4' (4.3-4.4m)
SG-T-7	8.0 (2.4)	Stable, stage II caliche 3-8' (0.9-2.4m) cementation at 8' (2.4m) exceeded capacity of Ford Auto-Dig backhoe
SG-T-8	12.0 (3.7)	Stable, stage III caliche 11-12 (3.4-3.7m)
SG-T-9	13.5 (4.1)	Stable
SG-T-10	3.1 (0.9)	Stable, stage III caliche 2-3.1' (0.6-0.9m) exceeded capacity of Ford Auto-Dig backhoe
SG-T-11	15.1 (4.6)	Stable, stage II caliche 7.1-8.6' (2.2-2.6m)
SG-T-12	14.9 (4.5)	Stable, stage I caliche 2.3-7.4' (0.7-2.3m)
SG-T-13	15.0 (4.6)	Stable
SG-T-14	14.0 (4.3)	Stable
SG-T-15	14.2 (4.3)	Stable
SG-T-16	14.0 (4.3)	Stable, stage I caliche 0.8-1.7' (0.2-0.5m) and 3.3-5.2' (1.0-1.6m)
SG-T-17	14.4 (4.4)	Stable

ENGINEERING FIELD ACTIVITIES - TRENCHES
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
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TABLE
3

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EXPLANATION

SURFICIAL GEOLOGIC UNITS

□ A1, A2 and A3 - stream channel/terrace and eolian deposits

■ A4 - playa deposits

■ S5To - Ogallala Formation

Following Intermediate Screening, the Ogallala Formation was designated as non-rock in the Central High Plains due to its unconsolidated nature.

SYMBOLS

● Boring

— Trench

--- Shallow Seismic Refraction Line

S(R) Both Shallow Seismic and Resistivity Line

NOTE: For detailed description of geologic units, see Table A-1

GENERALIZED GEOLOGIC MAP AND
FIELD ACTIVITY LOCATIONS
STERLING, COLORADO, CENTRAL HIGH PLAINS CDP

MX SITING INVESTIGATION
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2

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deposits cover the remaining six percent of the area in generally thin sequences overlying the Ogallala Formation. Within the site, the Ogallala Formation is unconformably underlain by either the Brule Formation or the Pierre Shale at depths ranging from 180 feet (55 m) to over 200 feet (61 m).

The site slopes gently to the east at a gradient of 0.3 percent. Local relief generally does not exceed a few tens of feet, except near major widely spaced drainages where channels are typically 20 to 40 feet (6 to 12 m) deep and 0.25 to 0.40 nm (0.46 to 0.74 km) wide, with banks of three to 20 percent slope. A summary of soil and terrain conditions for each surficial geologic unit is shown in Table 4.

2.3 SUBSURFACE CONDITIONS

2.3.1 Soil Profiles

The composition of soils with depth is illustrated by the soil profiles shown in Figures 3 and 4. The surficial loess (eolian silt: ML, CL) and sheet sand (SM, SP) deposits extend to depths ranging from two to 30 feet (0.6 to 9 m). They are underlain by the Ogallala Formation which is predominantly composed of sand (SP) and silty sand (SM) with minor interbeds of gravel.

2.3.2 Depth to Shallow (<150 feet; <46 m) Rock and Water

Boring logs, regional literature and geologic maps indicate depth to rock is greater than 150 feet (46 m) and averages over 200 feet (61 m) within the site. The rock units consist

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS) (b)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S) (c)	AREAL EXTENT (SITE)		
					nm ² (km ²)	PERCENT	
Fluvial and Stream Terrace Deposits (A1 A2)	Quaternary	0-10 (0-3)	Gravelly Sand	SW	8 (27)	4	
Eolian Silt Deposits (loess) (A3l)	Pleistocene	0-20 (0-6)	Clayey Silt	ML	29 (99)	14	
Sheet and Dune Sands (A3s A3d)	Quaternary	0-50 (0-15)	Silty Sand	SM	12 (41)	6	P
Playa Deposits (A4)	Quaternary	0-10 (0-3)	Silty Clay	CL	4 (14)	< 2	
Ogallala Formation (S5To)	Pliocene	190-210 (58-64)	Clayey Sand to Gravel	SC-GP	152 (520)	74	P

NOTES:

- (a) For generic description of geologic units, see Table A-1.
- (b) Thickness range represents the most common occurrence.
- (c) For description of USCS symbols, see Table A-2.
- (d) For description of stage of caliche, see Figure A-1.
- (e) Estimate of drainage depths based on: field observations and topographic maps

AL EXTENT (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
(km ²)	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/PATINA	STAGE OF CALICHE (d)	SLOPE (PERCENT)	DRAINAGE DEPTHS (e) FEET (METERS)	
8 27)	4	Well	None	Cobble	Not Applicable	None	3-20	5-60 (2-18)	
29 99)	14	Poor	Weak	Sand	Not Applicable	I	0-25	5-60 (3-18)	
2 41)	5	Poor-Well	Weak	Sand	Not Applicable	I	0-30	5-30 (2-9)	
4 4)	< 2	Poor	None	Sand	Not Applicable	None	0-10	2-10 (1-3)	
52 20)	74	Poor-Well	Weak-Strong	Cobble	Not Applicable	None-IV	0-15	5-60 (2-18)	

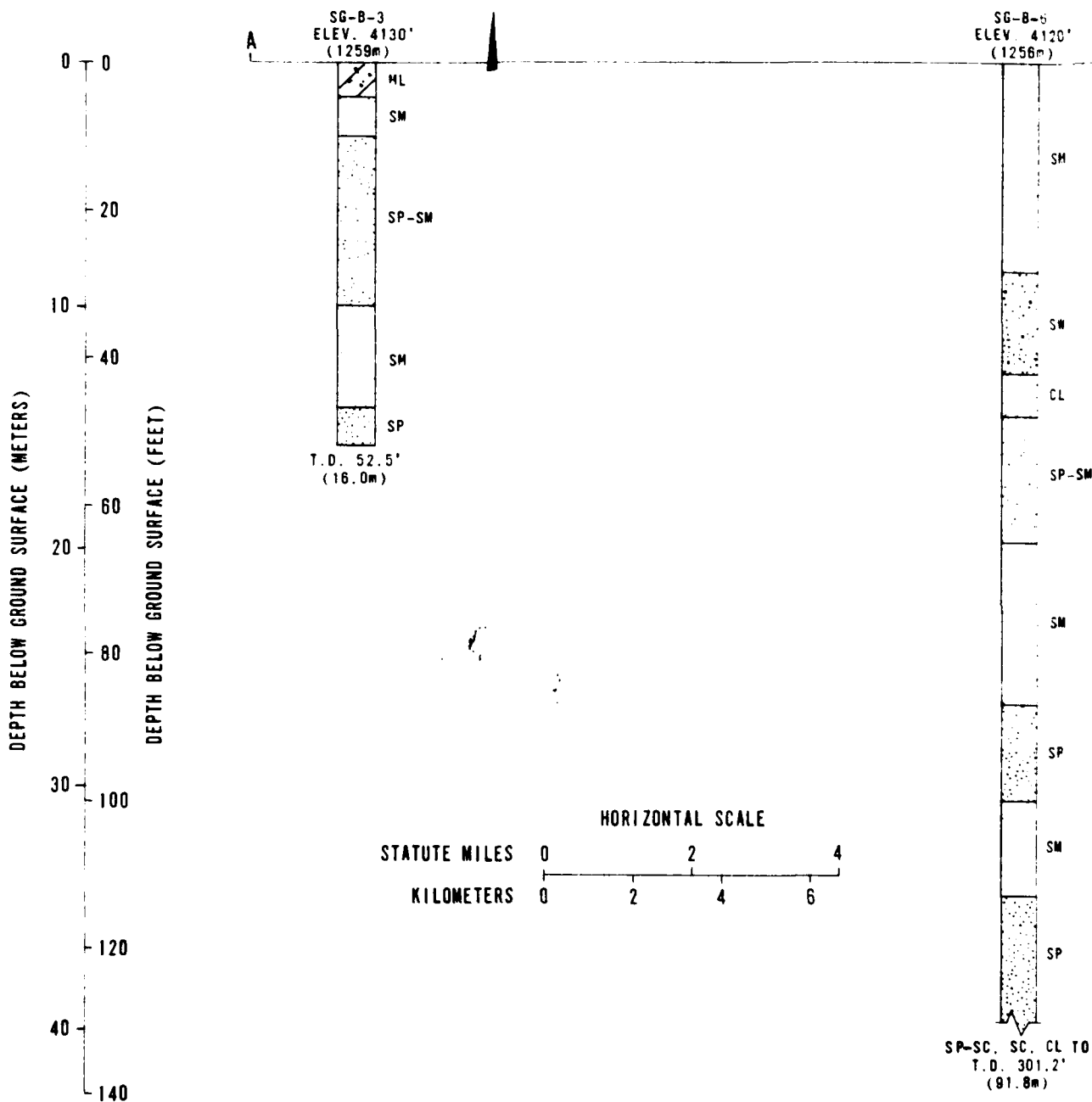
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DESCRIPTION OF SURFICIAL
GEOLOGIC UNITS
STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

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TABLE
4

FUGRO NATIONAL, INC.

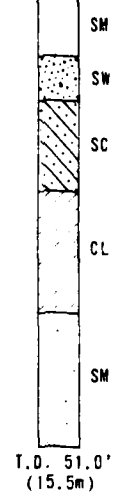


- NOTES:
1. Ground surface elevations shown at location of borings are approximate
 2. T.D. = Total Depth
 3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the appendix

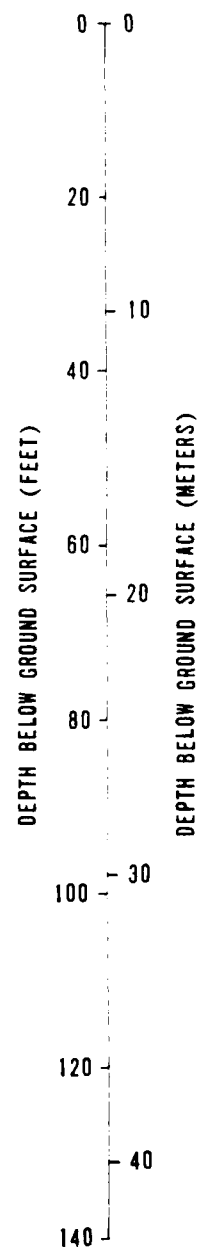
SG-B-6
ELEV. 4120'
(1256m)



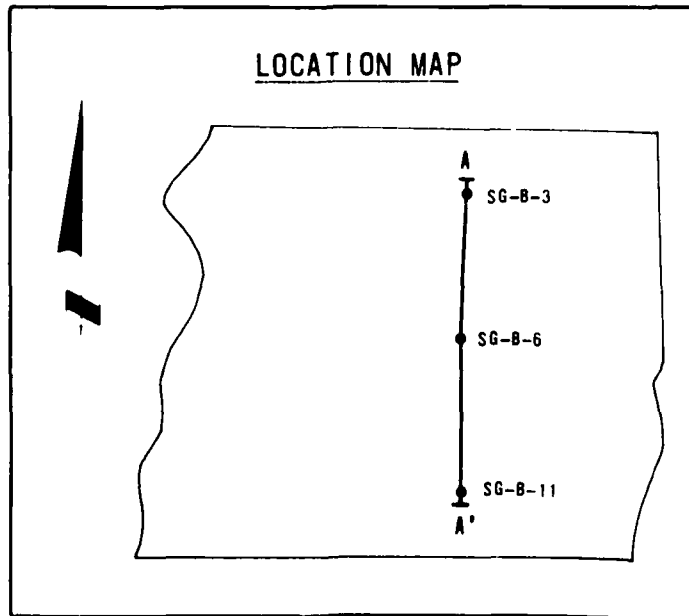
SG-B-11
ELEV. 4017'
(1224m)



A'



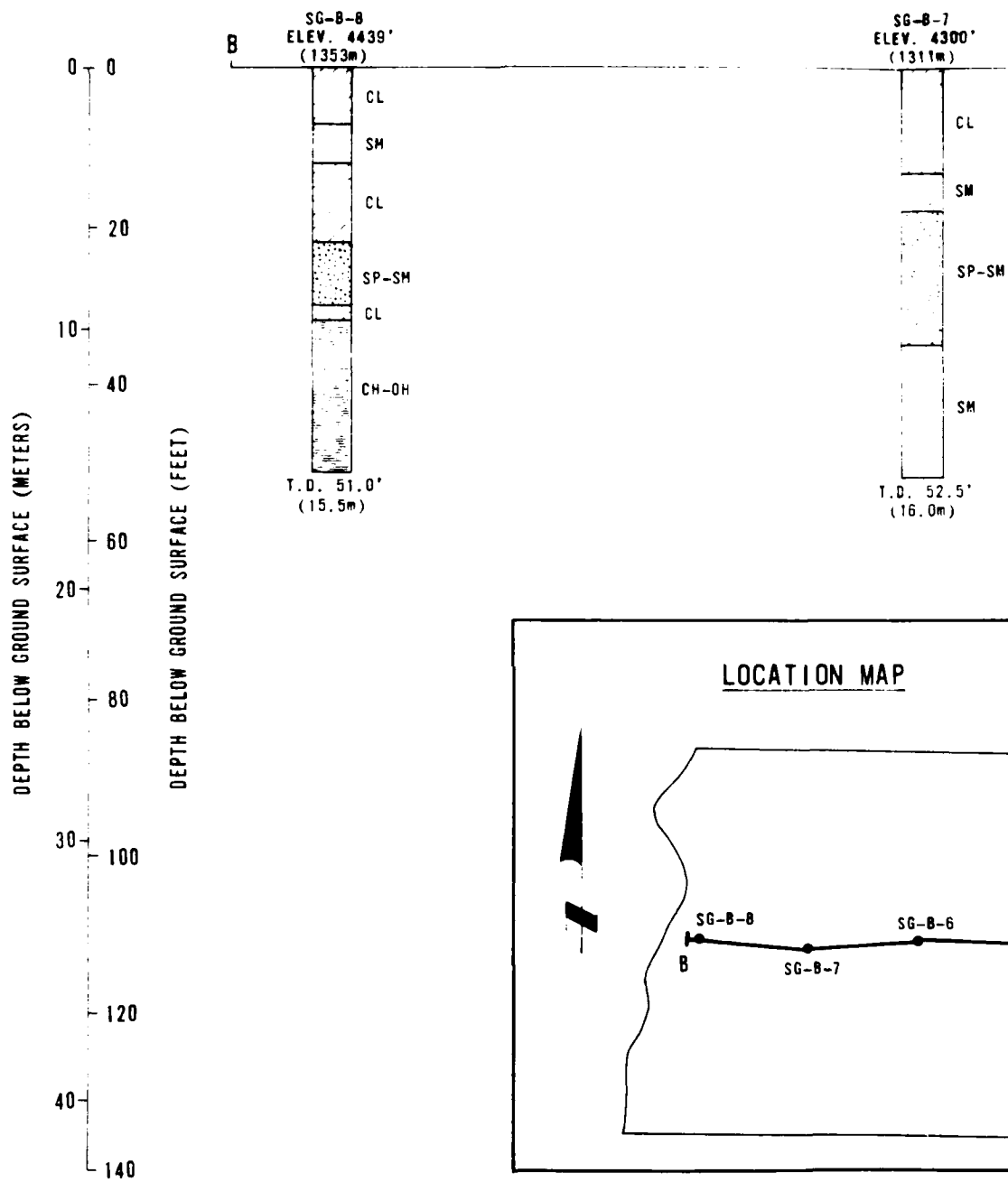
LOCATION MAP



e approximate
Unified Soil
endix

2

SOIL PROFILE AA' STERLING, COLORADO CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMS	FIGURE 3
FUGRO NATIONAL, INC.	

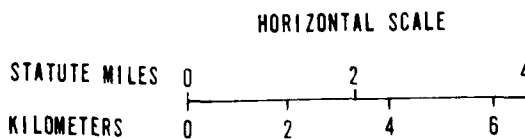
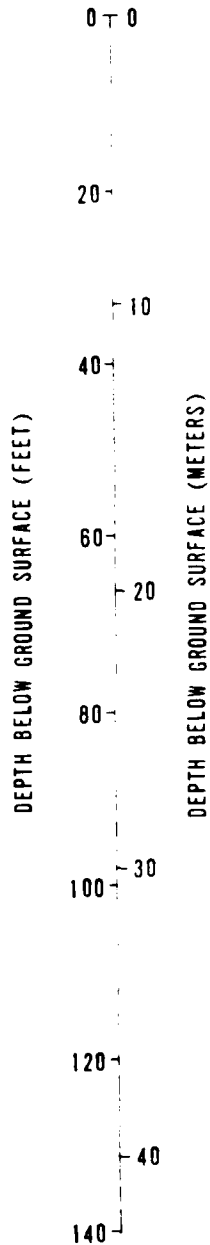
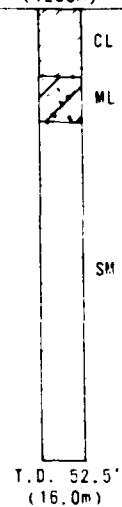
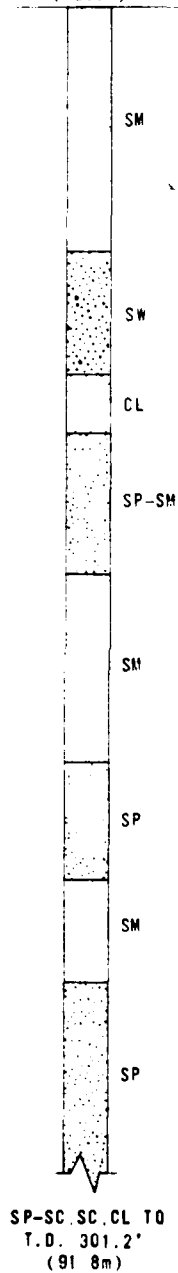


- NOTES:
1. Ground surface elevations shown at location of borings are approximate
 2. T.D.= Total Depth
 3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the appendix

SG-B-6
ELEV. 4120'
(1256m)

SG-B-5
ELEV. 3884'
(1208m)

B'



are approximate
the Unified Soil
appendix

2

SOIL PROF
STERLING,
CENTRAL HIGH

MX SITING INVESTIGA
DEPARTMENT OF THE AIR FOR

FUGRO NATI

SG-B-6
ELEV. 4120'
(1256m)

SG-B-5
ELEV. 3884'
(1208m)

B'

SM
SW
CL
SP-SM
SM
SP
SM
SP
SC CL TO
301.2'
(8m)

CL

ML

SM

T.D. 52.5'
(16.0m)

0 + 0

20

10

40

60

20

80

100

30

120

40

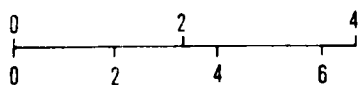
140

DEPTH BELOW GROUND SURFACE (FEET)

DEPTH BELOW GROUND SURFACE (METERS)

HORIZONTAL SCALE

STATUTE MILES
KILOMETERS



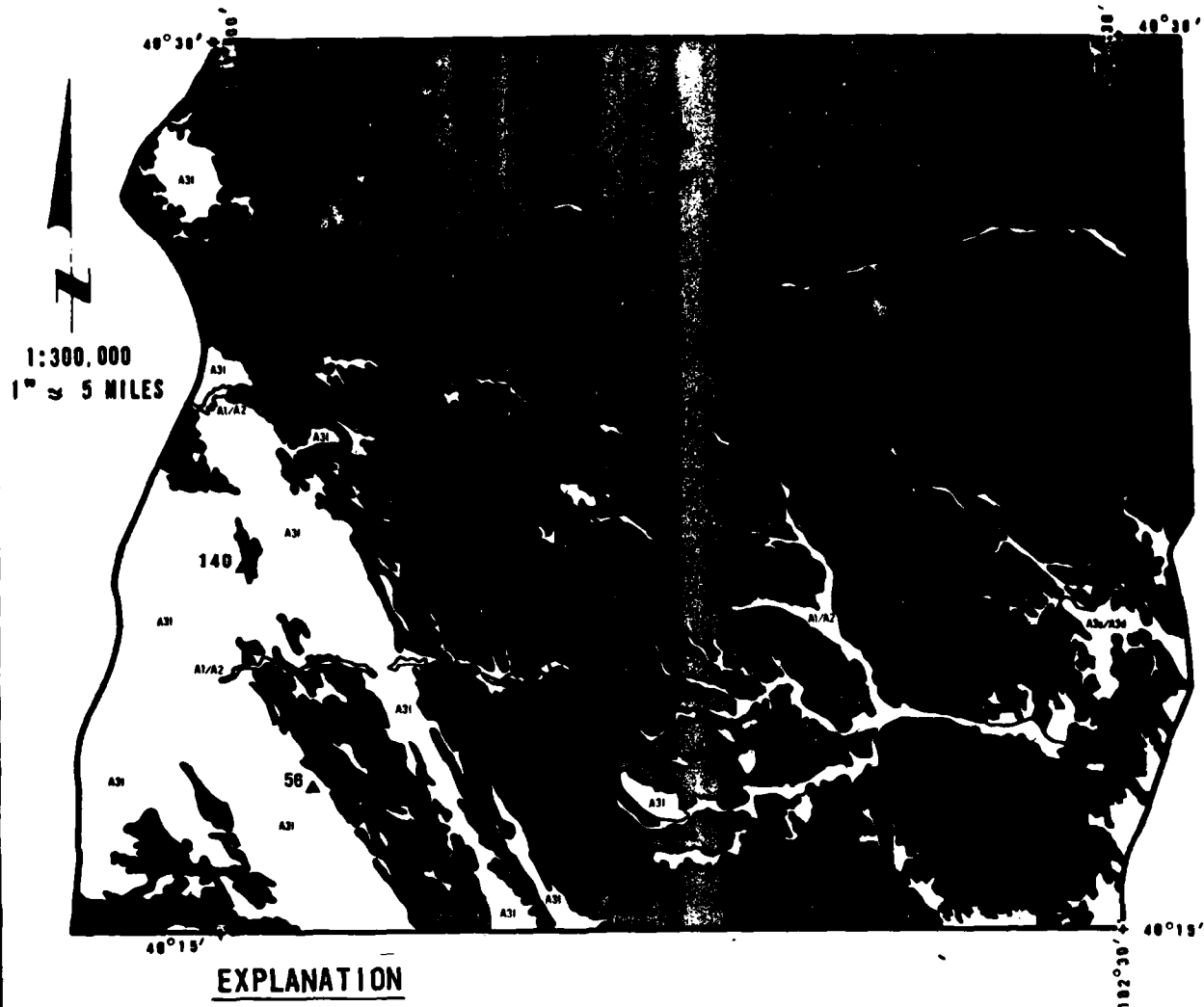
SOIL PROFILE BB'
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSC

FIGURE
4

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3



EXPLANATION

SURFICIAL GEOLOGIC UNITS

- A1/A2 and A3 - fluvial/terrace deposits and eolian deposits (>10 feet thick)
- A4 - playa deposits
- A3(S5To) - Ogallala Formation overlain by thin mantle (<10 feet thick) of eolian deposits

Following Intermediate Screening, the Ogallala Formation was designated as non-rock due to its unconsolidated nature.

SYMBOLS

- 140 Depth to ground-water table in feet
- Average depth to excavatable rock is >150 feet
- Depth to rock unknown

NOTE: For detailed description of geologic units, see Table A-1

GENERALIZED GEOLOGIC MAP AND
SELECTED SUBSURFACE FEATURES
STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
5

FUGRO NATIONAL INC.

primarily of shale and are considered excavatable. Figure 5 shows portions of the site in which water is estimated to be encountered within a depth of 150 feet (46 m) below the ground surface. Based on drilling logs and published information, the depth to water generally averages 140 feet (43 m) in approximately 50 percent of the area. Figure 6 shows generalized geologic cross sections of the site.

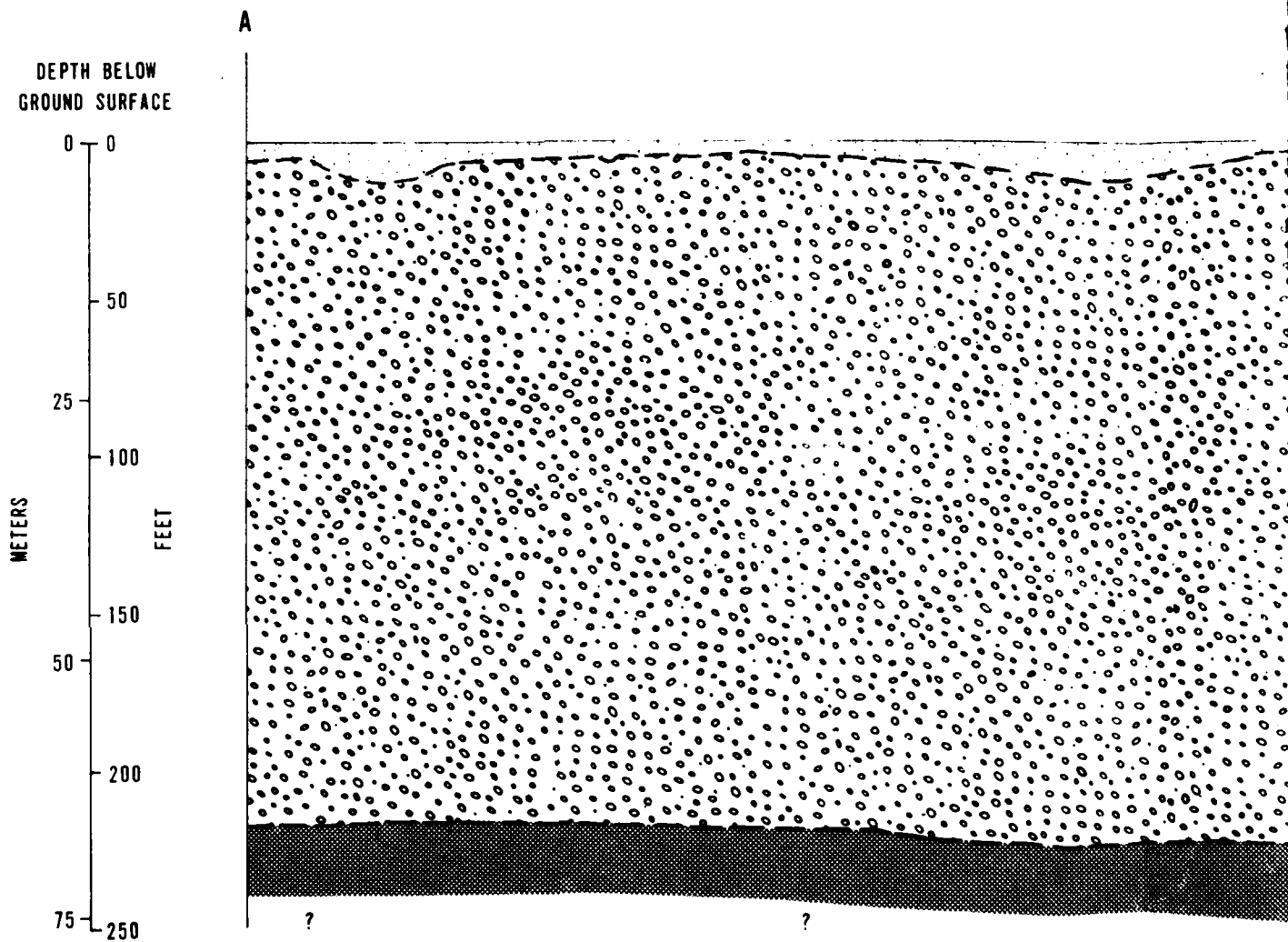
2.4 GEOPHYSICAL PROPERTIES

Results of shallow seismic and conductivity investigations are presented in Tables 5 and 6, respectively. No bedrock velocities (greater than 7000 fps) were detected by the shallow seismic refraction surveys. A near surface layer with a maximum thickness of 20 feet (6 m) and a velocity in the 1000 to 2000 fps (300 to 610 mps) range was observed at most locations. Velocities of underlying layers were between 2000 and 6100 fps (610 and 1860 mps). Average conductivities in the upper 50 feet (15 m) of the site soils were greater than 0.004 mhos/m.

2.5 ENGINEERING PROPERTIES

Engineering properties of the subsoils representing various geologic units were determined from laboratory tests. The tests consisted of: classification, consolidation, shear strength, compaction, CBR and chemical. The range of engineering and geophysical properties of the predominant geologic units at the Sterling site is summarized in Table 7.

The loess deposits are primarily formed of uncemented, unsaturated, poorly graded and slightly plastic clayey silt with up to



EXPLANATION

NOTES:

1. The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.

2. For a detailed description of geologic units see Table A-1.



Undifferentiated surficial units

Predominantly eolian (A3) deposits, with minor fluvial/terrace (A1/A2) playa (A4) deposits



Ogallala Formation (S5To)

Unconsolidated sand, silt, gravel, cobbles or clay with local caliche caprock

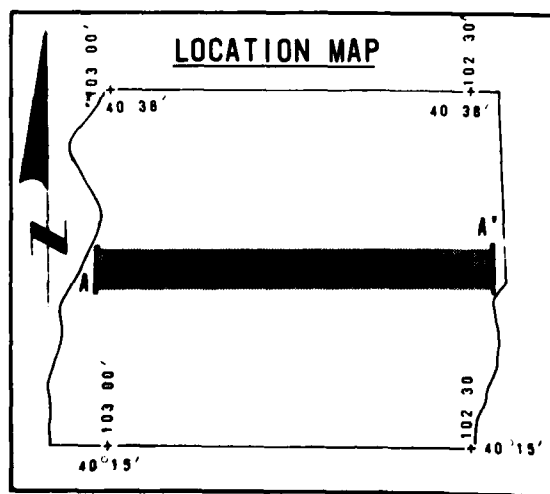
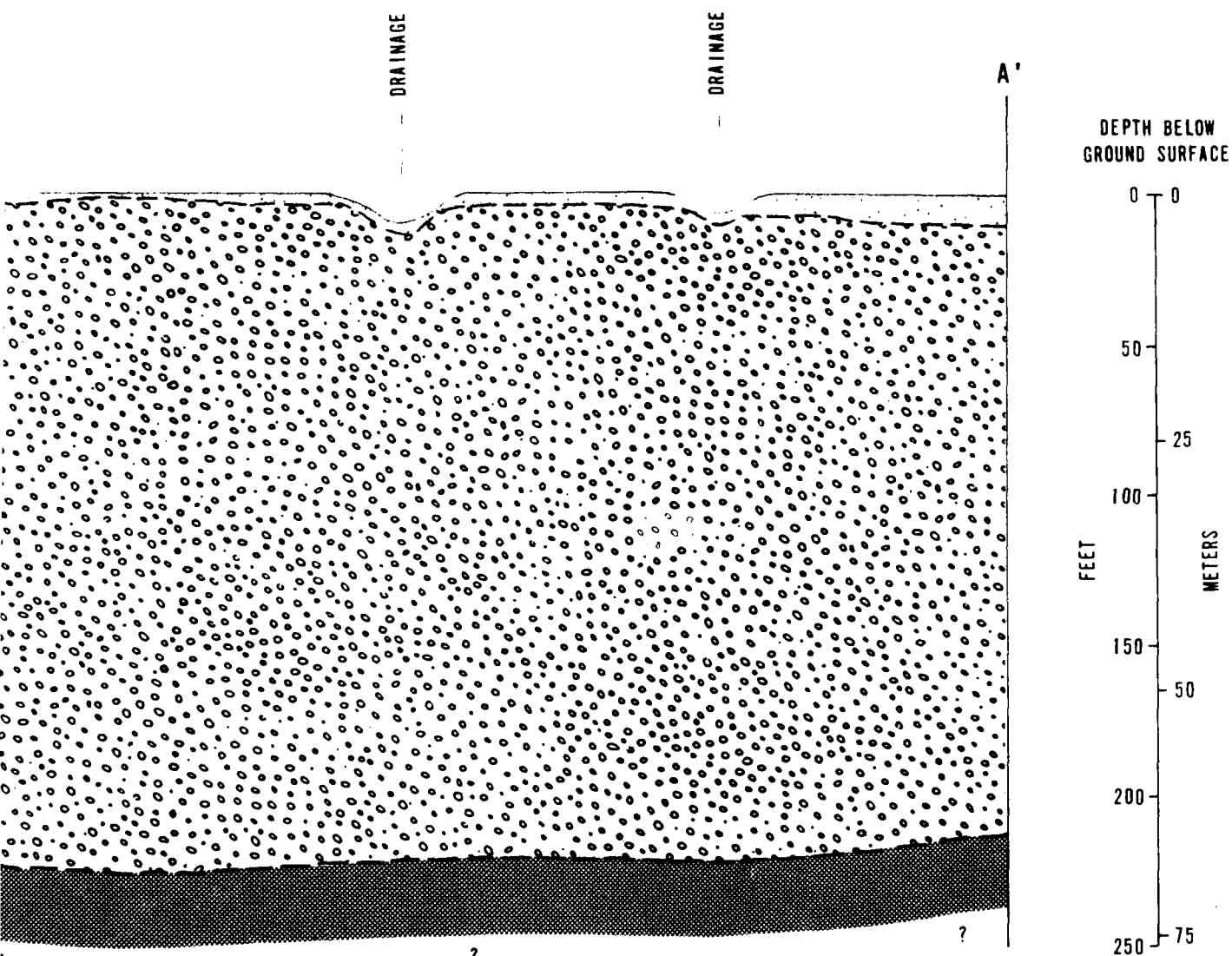


Pierre Shale (S3Kp)

Excavatable, fissile shale with thin bentonite interbeds



Approximate geologic contact, queried where inferred

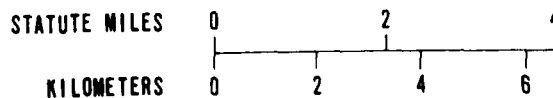


Horizontal Scale: 1" \approx 2 Miles (3km)

Vertical Scale: 1" = 50' (15m)

Vertical Exaggeration: 211X

HORIZONTAL SCALE



GENERALIZED GEOLOGIC CROSS SECTION
STERLING SITE, COLORADO
CENTRAL HIGH PLAINS CSP

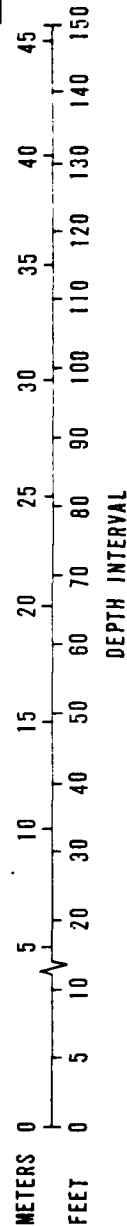
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
6

FUGRO NATIONAL, INC.

2

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)		DEEPER REFRACTORS		* ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
			DEPTH	VELOCITY	
SG-S-1	4000 (1220)	▲	-	-	195 (59)
SG-S-2	950 (290) 1750 (530)	▲ 2650 (810)	▲	-	147 (45)
SG-S-3	1450 (440)	▲ 2400 (730)	▲	-	133 (41)
SG-S-4	1100 (340) 2050 (620)	▲ 3100 (940)	▲	-	140 (43)
SG-S-5	1860 (510)	▲ 2200 (670)	▲	-	148 (45)
SG-S-6	1250 (380)	▲ 3350 (1020)	▲	-	136 (41)
SG-S-7	2300 (700)	▲ 3150 (960)	▲	-	156 (48)
SG-S-8	1100 (340) 2150 (660)	▲ 2700 (820)	▲	-	165 (50)
SG-S-9	1330 (410) 3530 (1080)	▲ 4660 (1420)	▲	-	118 (36)
SG-S-10	1200 (370)	▲ 2100 (640)	▲	-	134 (41)
SG-S-11	1450 (440) 3500 (1070)	▲ 4700 (1430)	▲	-	203 (62)
SG-S-12	1300 (400)	▲ 2600 (790)	▲	-	163 (50)
SG-S-13	2800 (850)	▲	-	-	136 (41)
SG-S-14	1450 (440)	▲ 2950 (900)	▲	-	150 (46)



* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS

TABLE
5

FUGRO NATIONAL, INC.

ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos m)**
R-1	.016
R-2	.024
R-3	.009
R-4	.016
R-5	.015
R-6	.026
R-7	-
R-8	-
R-9	.033
R-10	.038
R-11	.011
R-12	.015
R-13	.022
R-14	.036

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

VX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE
6

FUGRO NATIONAL, INC.

ENGINEERING AND GEOPHYSICAL PROPERTIES		A3L	
UNIFIED SOIL CLASSIFICATION SYMBOL(S)		ML, CL-ML, CL	SW.
GENERAL PROPERTIES			
DRY DENSITY	pcf(kg m ³)	82-115 (1314-1842)	
MOISTURE CONTENT	(%)	6-23	
DEGREE OF SATURATION	(%)	15-60	
SPECIFIC GRAVITY		2.6-2.7	
DEGREE OF CEMENTATION		None to weak	
COMPRESSIONAL WAVE VELOCITIES	fps(mps)	700-2200 (213-671)	
ELECTRICAL CONDUCTIVITY	(mhos m)	0.027-0.056	
GRAIN SIZE DISTRIBUTION (%)			
BOULDERS	>12 inches (30cm)	0	
COBBLES	3 to 12 inches (8 to 30cm)	0	
GRAVEL		0	
SAND		24-42	
SILT AND CLAY		58-76	
PLASTICITY DATA			
LIQUID LIMIT		28-48	
PLASTICITY INDEX		7-25	
COMPRESSIBILITY DATA			
COMPRESSION AT 4 ksf (192 kN m ²)	(%)	3-4	
SWELL OR COLLAPSE UPON SATURATION	(%)	± 1-2	
SHEAR STRENGTH DATA			
UNCONFINED COMPRESSION	ksf(kN m ²)	1-3 (48-144)	
CD TRIAXIAL COMPRESSION		DNA	C
DIRECT SHEAR	ksf(kN m ²)	1-2 (48-96)	
COMPACTION AND CBR DATA			
MAXIMUM DRY DENSITY	pcf(kg m ³)	115-125 (1842-2002)	
OPTIMUM MOISTURE CONTENT	(%)	10-15	
CBR AT 90% RELATIVE COMPACTION		4-10	

GEOLOGIC UNITS

S5to	A3s
SW, SM, SP, SC, GW, ML, CL	SM
95-128 (1522-2050)	95-110 (1522-1762)
3-20	2-6
13-85	10-30
2.6-2.75	2.65
Weak to moderate	None to weak
900-4950 (274-1509)	850-1350 (259-411)
0.010-0.020	0.062 ±
0	0
0-20	0
0-34	0-2
14-98	30-61
2-54	36-48
NP-40	NP
NP-20	NP
1-3 (48-144)	2-3
±1	±1-2
1-3 (48-144)	DNA
C = 0.2 Ksf (10) $\phi = 33$	C = 0.1 (5) $\phi = 30$
1-3 (48-144)	DNA
DNA	DNA
DNA	DNA
DNA	DNA

RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSU

TABLE
7

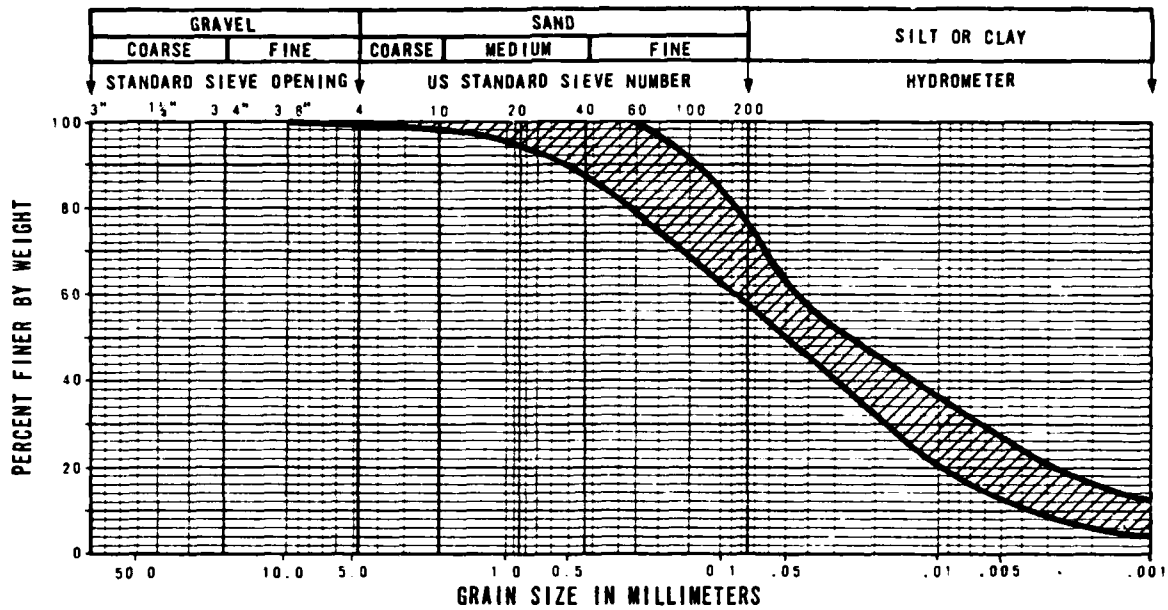
FUGRO NATIONAL, INC.

30 percent sand. They have a moderately high shear strength and are moderately compressible.

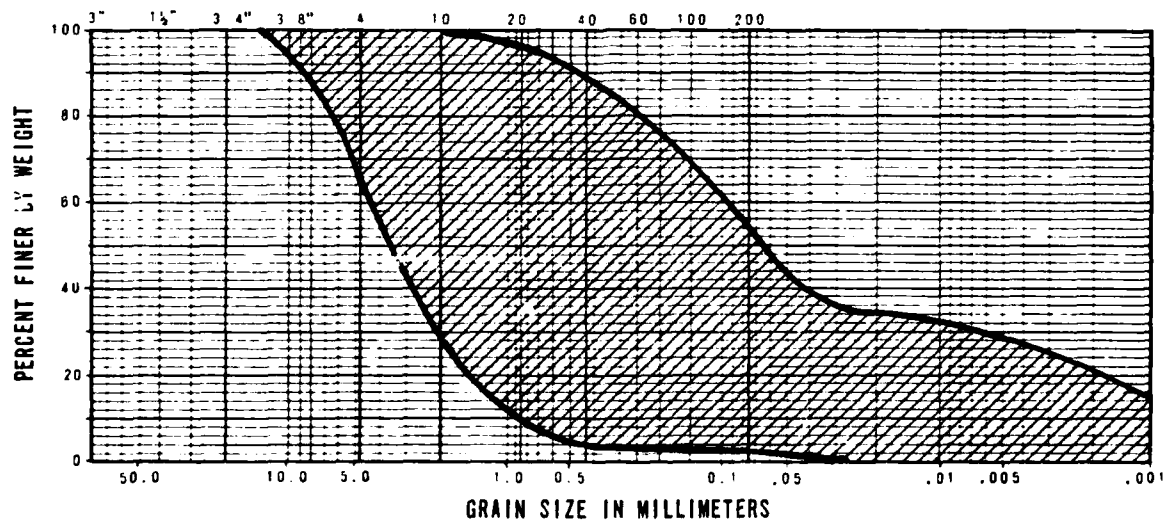
The sheet sand deposits consist of poorly graded, silty, fine sands. They possess moderate shear strength and are moderately compressible.

The Ogallala Formation is generally formed of uncemented, mostly unsaturated and well graded sands and silty sands with varying amounts of gravel and local caliche caprock. It has high shear strength and low compressibility. Range of gradation of the three geologic units is shown in Figures 7 and 8.

Representative logs of three borings and three trenches from the site are contained in Appendix B. Results of the shear strength, CBR, and chemical tests performed on soil samples from the site and a summary of all the laboratory tests performed on soil samples obtained from boring SG-B-6 are also included in Appendix B.



A31



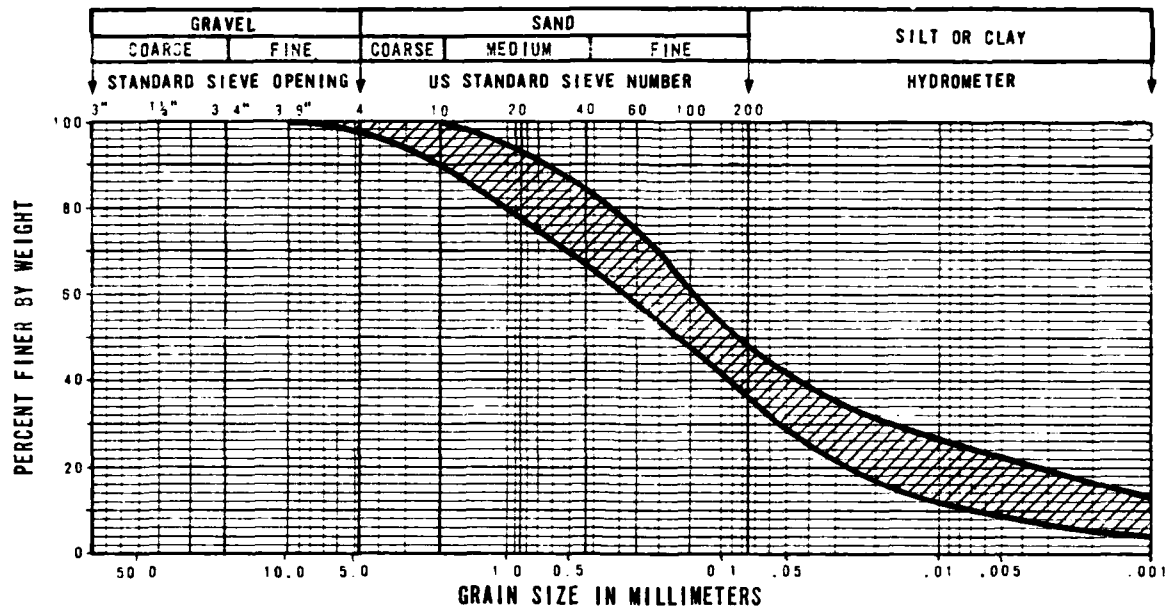
S5To

RANGE OF GRADATION OF GEOLOGIC UNITS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

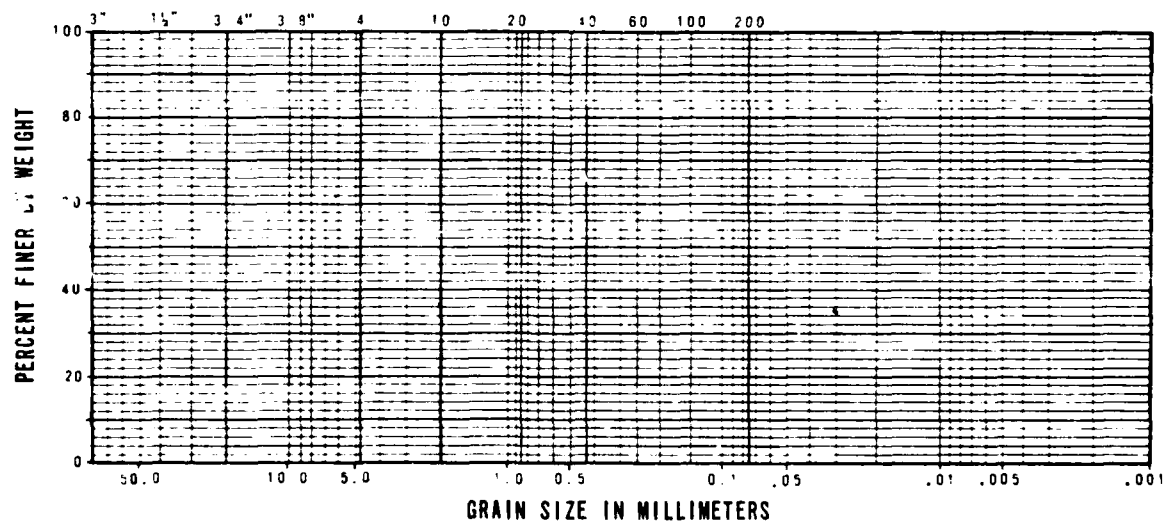
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
7

FUGRO NATIONAL, INC.



A3s



RANGE OF GRADATION OF GEOLOGIC UNITS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
8

FUGRO NATIONAL, INC.

3.0 SCOTT CITY SITE

The Scott City Characterization site covers an area of 390 nm² (1338 km²) and is situated in Thomas and Logan counties in northwestern Kansas. US highways 70 and 83 form the northern and eastern boundaries of the site, respectively. A network of graded farm roads traverses the site and provides access to all areas within.

3.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site are presented in Table 8. Detailed information about the soils engineering field activities (17 borings and 16 trenches) is summarized in Tables 9 and 10.

Locations of all the field activities are shown in Figure 9.

3.2 SURFICIAL GEOLOGY AND TERRAIN

Loess (eolian silt) is the predominant surficial geologic unit covering approximately 90 percent of the site. Fluvial, stream terrace, and playa deposits cover most of the remaining ten percent and generally overlie the loess deposits. The fluvial and stream terrace deposits range from gravelly sand to silty clay, whereas, playa deposits are primarily composed of plastic clays. Other surficial geologic units at the site include the Ogallala Formation, Pierre Shale, and undifferentiated soils.

The site slopes to the east at a general gradient of 0.3 percent. Local relief generally does not exceed a few tens of feet and the predominant surficial deposit (loess) forms zero to

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological mapping stations	22
Shallow refraction	29
Electrical conductivity	20

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
12	50 (15)
4	100 (30)
1	300 (91)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
1	11 (3)
15	13 (4)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture density	167
Specific gravity	6
Sieve analysis	37
Hydrometer	18
Atterberg limits	27
Consolidation	2

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	6
Triaxial compression	5
Direct shear	5
Compaction	2
CBR	2
Chemical analysis	2

**SCOPE OF FIELD AND LABORATORY
ACTIVITIES**

SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSTABLE
8**FUGRO NATIONAL, INC.**

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
SY-B-1	102.5 (31.2)	Rotary Wash	P, SS
SY-B-2	102.2 (31.2)	Rotary Wash	P
SY-B-3	51.0 (15.5)	Hollow Stem Auger	D
SY-B-4	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-5	51.5 (15.7)	Hollow Stem Auger	P, D
SY-B-6	302.3 (92.1)	Rotary Wash	P, SS, D
SY-B-7	52.0 (15.8)	Hollow Stem Auger	P, D
SY-B-8	102.4 (31.2)	Rotary Wash	P, SS
SY-B-9	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-10	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-11	102.5 (31.2)	Rotary Wash	P
SY-B-12	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-13	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-14	52.5 (16.0)	Hollow Stem Auger	P, D
SY-B-15	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-16	51.0 (15.5)	Hollow Stem Auger	P, D
SY-B-17	51.0 (15.5)	Hollow Stem Auger	P, D

- * P = Pitcher sample (undisturbed)
 D = Fugro Drive sample (relatively undisturbed)
 B = Bulk sample (disturbed, but representative)
 SS = Split Spoon sample (disturbed, but representative)

ENGINEERING FIELD ACTIVITIES - BORINGS
 SCOTT CITY, KANSAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
 9

LEED NATIONAL, INC.

TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS AND REMARKS
SY-T-1	14.5 (4.4)	stable; non- to weakly cemented
SY-T-2	14.2 (4.3)	stable; non- to weakly cemented
SY-T-3	14.4 (4.4)	stable
SY-T-4	13.6 (4.1)	stable
SY-T-5	13.5 (4.1)	stable
SY-T-6	14.0 (4.3)	stable; non- to weakly cemented
SY-T-7	14.1 (4.3)	stable
SY-T-8	12.0 (3.7)	stable
SY-T-9	14.0 (4.3)	stable; non- to weakly cemented
SY-T-10	13.1 (4.0)	stable
SY-T-11	13.0 (4.0)	stable
SY-T-12	12.4 (3.8)	stable
SY-T-13	13.0 (4.0)	stable
SY-T-14	14.0 (4.3)	stable
SY-T-15	10.7 (3.3)	stable; weakly to moderately cemented
SY-T-16	12.7 (3.9)	stable

ENGINEERING FIELD ACTIVITIES - TRENCHES
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP




MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSQ

TABLE
10






FUGRO NATIONAL, INC.

EXPLANATION

SURFICIAL GEOLOGIC UNITS

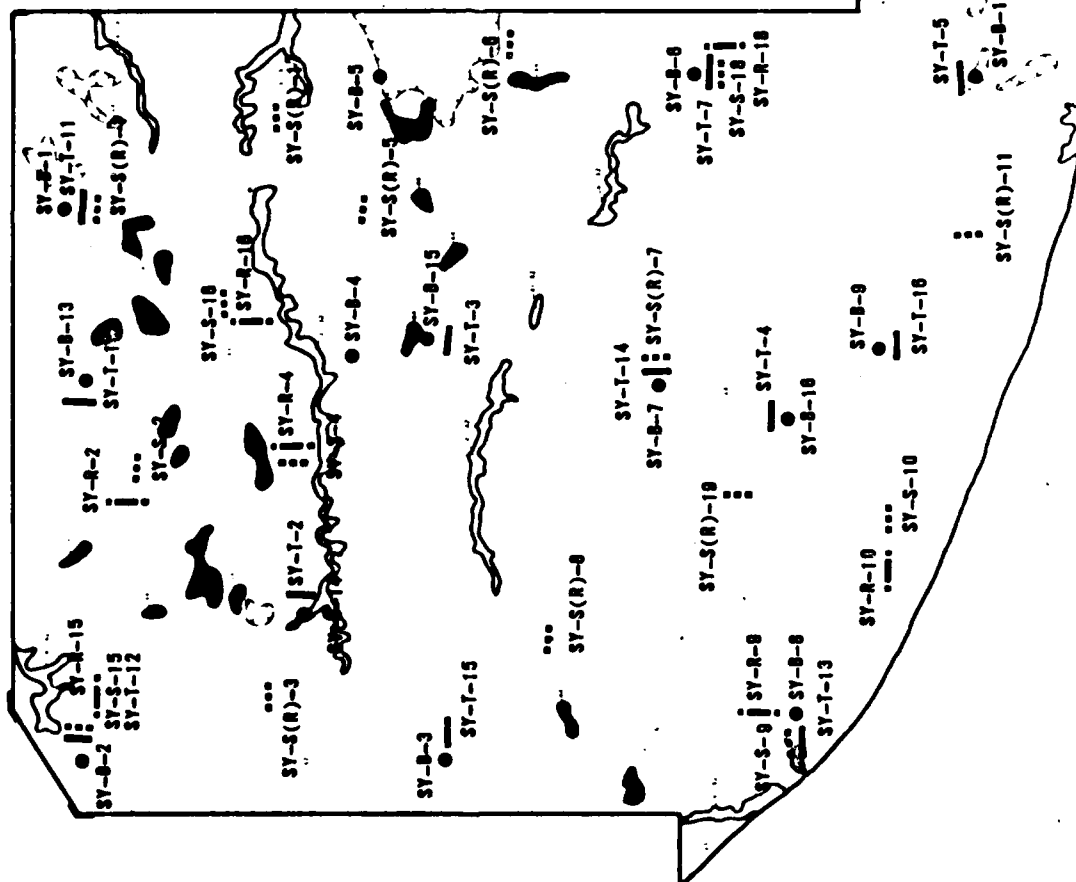
-  A1, A2 and A3 - stream channel terrace and eolian deposits
-  A4 - playa deposits
-  S5To - Ogallala Formation

SYMBOLS

-  Boring
-  Shallow Seismic Refraction Line
-  Resistivity (Conductivity) Line
-  S(R) Both Shallow Seismic and Resistivity Line
-  Trench

NOTES: 1. For detailed description of geologic units, see Table A-1.

2. Following Intermediate Screening, the Ogallala Formation was designated as non-rock in the Central High Plains due to its unconsolidated nature.



GENERALIZED GEOLOGIC MAP AND
FIELD ACTIVITY LOCATIONS
SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSQ

FIGURE

9

FUGRO NATIONAL, INC.

three percent slopes. Drainage channels are widely spaced, typically 20 to 30 feet (6 to 9 m) deep and 0.4 nm (0.74 km) wide, with banks of three to 18 percent slope. A summary of the soil and terrain conditions for each surficial geologic unit is shown in Table 11.

3.3 SUBSURFACE CONDITIONS

3.3.1 Soil Profiles

Profiles of the soils encountered in the borings are shown in Figures 10 and 11. The surficial loess deposits, indicated as ML and CL in the figures, extend to an average depth of 35 feet (11 m). They are underlain by the Ogallala Formation which is indicated mostly as SM, SP and SC on the profiles. The Ogallala Formation is unconformably underlain by Pierre Shale, which occurs at an average depth of 145 feet (44 m). The Pierre Shale is believed to be the 7000 fps (2134 mps) seismic velocity refractor and is classified as "excavatable" rock. It is approximately 700 feet (213 m) thick and is underlain by over 2000 feet (610 m) of Mesozoic shale, limestone, and sandstone.

3.3.2 Depth to Shallow (<150 ft; <46 m) Rock and Water

Excavatable rock occurs at an average depth of 145 feet (44 m) across the site. Figure 12 indicates that depth to water is greater than 100 feet at locations where water depths have been measured. Based on drilling logs and published information it generally averages between 125 and 150 feet (38 and 46 m) in over 50 percent of the area. Figure 13 presents a generalized geologic cross section of the site.

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS) (b)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S) (c)	AREAL EXTENT (SITE)		GRADE
					nm ² (km ²)	PERCENT	
Undifferentiated Non-Rock Deposits (Au)	Quaternary	15-25 (5-8)	Silty Clay	CL	< 1	< 1	Poor
Fluvial Deposits (A1)	Quaternary	20-30 (6-9)	Gravelly Sand to Silty Clay	SW to CL	8 (27)	2	Poor
Stream Terrace Deposits (A2)	Quaternary	20-30 (6-9)	Gravelly Sand to Silty Clay	SW to CL	4 (14)	1	Poor
Eolian Silt Deposits (loess) (A3l)	Pleistocene	30-40 (9-12)	Clayey Silt	ML	371 (1273)	94	Poor
Playa Deposits (A4)	Quaternary	5-15 (2-5)	Silty Clay	CL, CH	8 (27)	2	Poor
Ogallala Formation (S5To)	Pliocene	90-110 (27-34)	Clayey Silt to Gravel	ML to GP	< 1	< 1	Poor
Pierre Shale (S3Kp)	Cretaceous	600-800 (183-244)	Shale	-	< 1	< 1	Poor

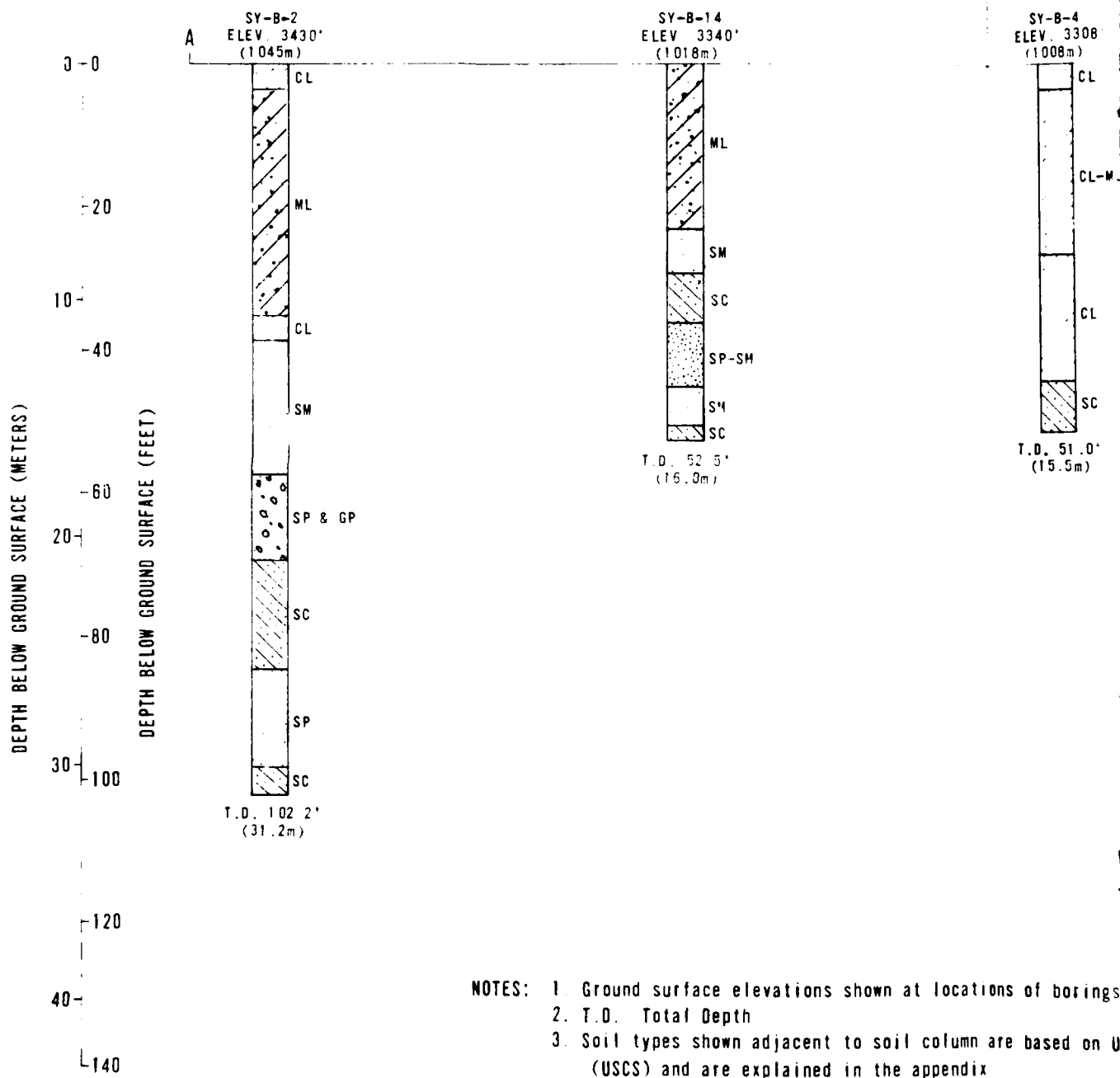
NOTES:

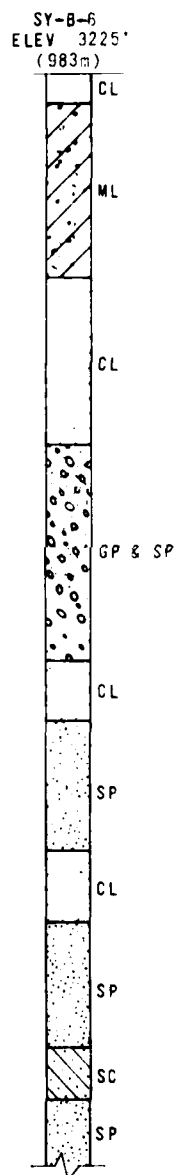
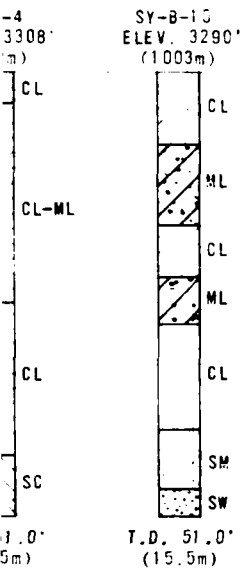
- (a) For generic description of geologic units, see Table A-1.
 (b) Thickness range represents the most common occurrence.
 (c) For description of USCS symbols, see Table A-2.
 (d) For description of stage of caliche, see Figure A-1.
 (e) Average value; estimate based on field observations and topographic maps.
 (f) Excavatable rock.

EAL EXTENT (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
² (km ²)	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/PATINA	STAGE OF CALICHE (d)	SLOPE (PERCENT)	DRAINAGE DEPTHS (e) FEET (METERS)	
< 1	< 1	Poor	None-Weak	Sand	Not Applicable	None-I	3-15	20-30 (6-9)	
8 (27)	2	Poor-Well	None-Weak	Gravel	Not Applicable	None-I	1-5	20-30 (6-9)	
4 (14)	1	Poor-Well	None-Weak	Gravel	Not Applicable	None-I	1-5	20-30 (6-9)	
371 (1273)	94	Poor	None-Weak	Sand	Not Applicable	None-I	0-3	20-30 (6-9)	
8 (27)	2	Poor	None	Silt	Not Applicable	None	0-1	2-5 (1-2)	
< 1	< 1	Poor-Well	Weak-Strong	Cobble	Not Applicable	I-II	0-4	None	
< 1	< 1	Poor	—	Sand	Not Applicable	—	6-25	None	(f)

2

DESCRIPTION OF SURFICIAL GEOLOGIC UNITS SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	TABLE 11 SAMSC
FUGRO NATIONAL, INC.	





SP, SM, SC TO 175' (53.3m)
PIERRE SHALE FROM
175' (53.3m) TO
T.D. 302.3' (92.1m)

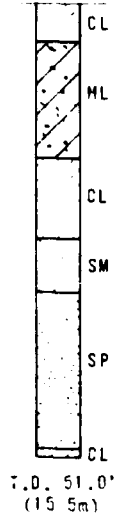
STATUTE MILES 0-
KILOMETERS 0

ings are approximate

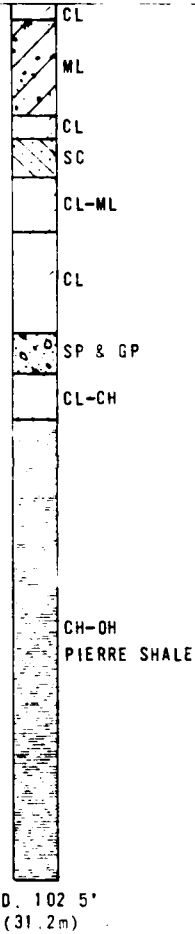
on Unified Soil Classification System

2

SY-B-10
ELEV. 3114'
(949m)



SY-B-11
ELEV. 2970'
(905m)



A'

0-0

20-

10-

40-

60-

-20

80-

100-

-30

120-

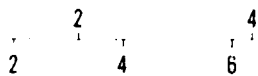
-40

140-

DEPTH BELOW GROUND SURFACE (FEET)

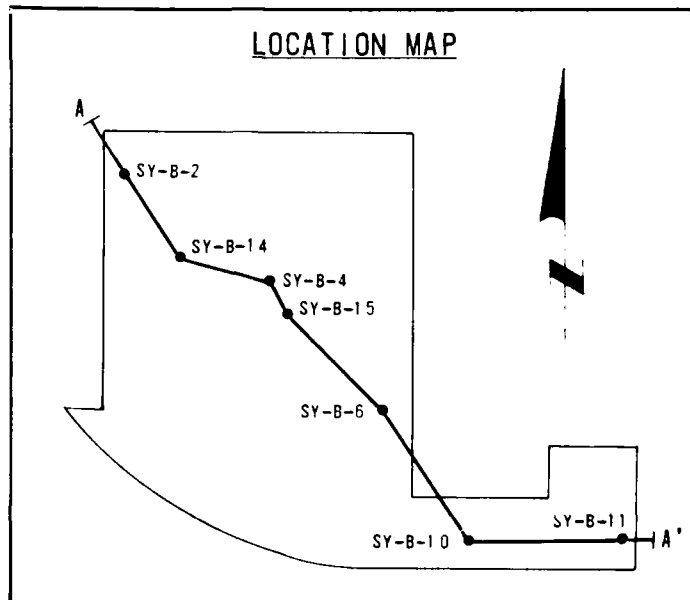
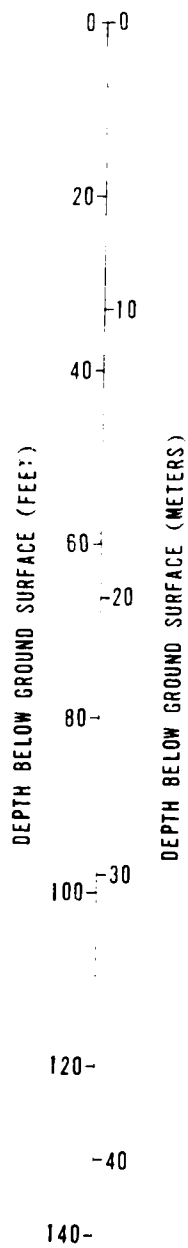
DEPTH BELOW GROUND SURFACE (METERS)

HORIZONTAL SCALE



3

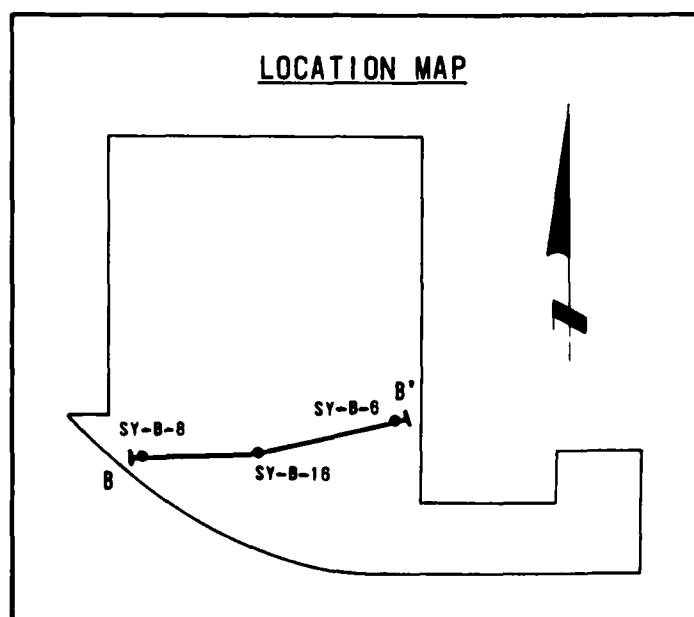
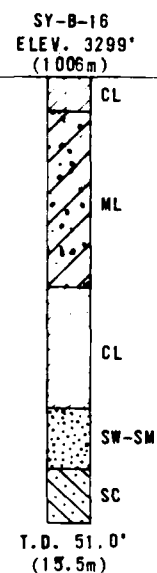
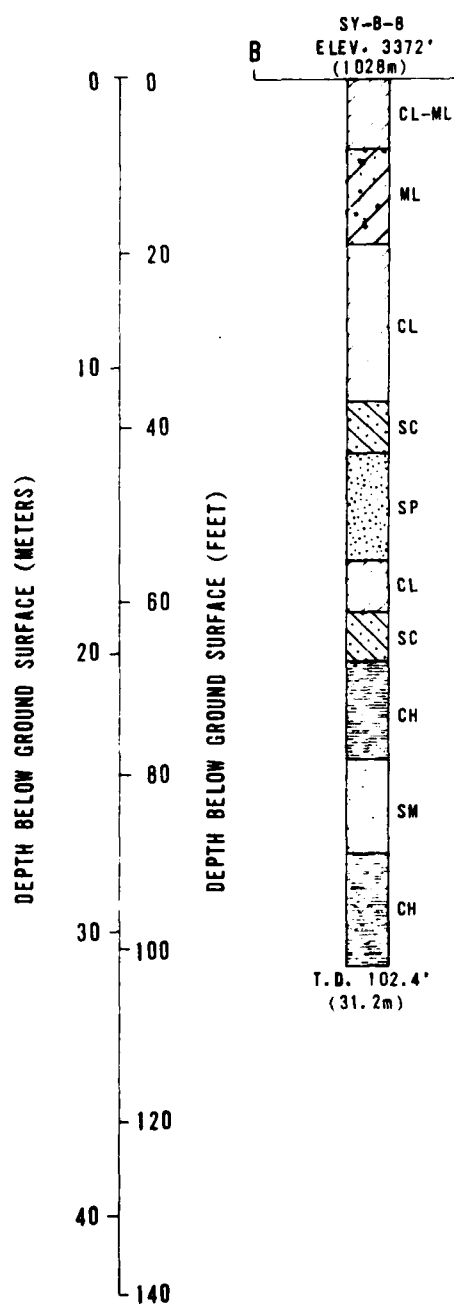
A'

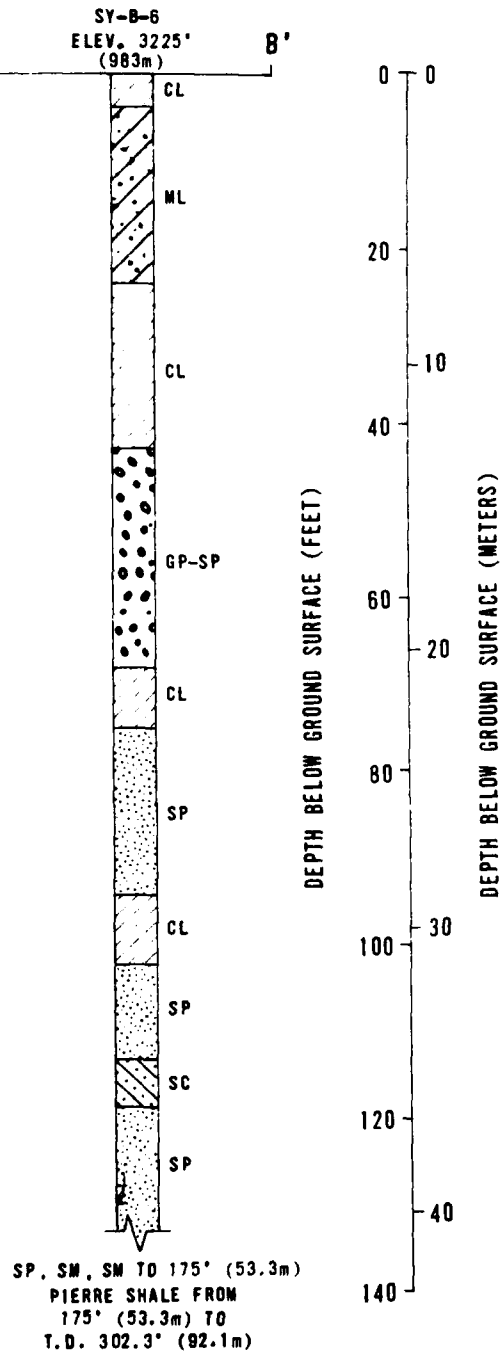


4

SOIL PROFILE AA' SCOTT CITY, KANSAS CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	SAMSC
FUGRO NATIONAL, INC.	

FIGURE
10





- NOTES: 1. Ground surface elevations shown at location of borings are approximate
2. T.O. = Total Depth
3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the appendix



SOIL PROFILE BB'
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
11

FUGRO NATIONAL, INC.

EXPLANATION

SURFICIAL GEOLOGIC UNITS

□ A1/A2 and A31 - fluvial/terrace and eolian silt deposits

■ A4 - playa deposits

■ S5To - Ogallala Formation

■ S3Kp - Pierre Shale

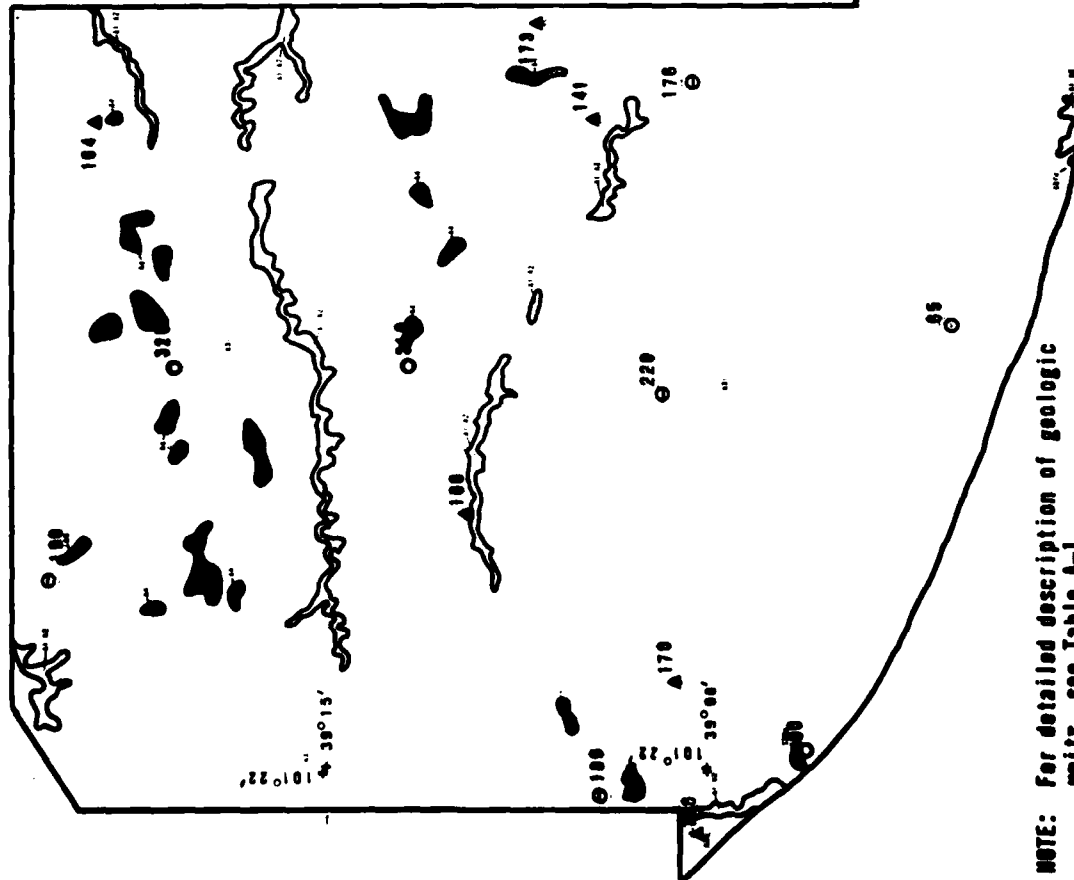
Following Intermediate Screening, the Ogallala Formation was designated as non-rock due to its unconsolidated nature.

SYMBOLS

▲ 104 Depth to ground-water table in feet

○ 100 Depth to excavatable rock in feet

Depth to rock is >1500 feet



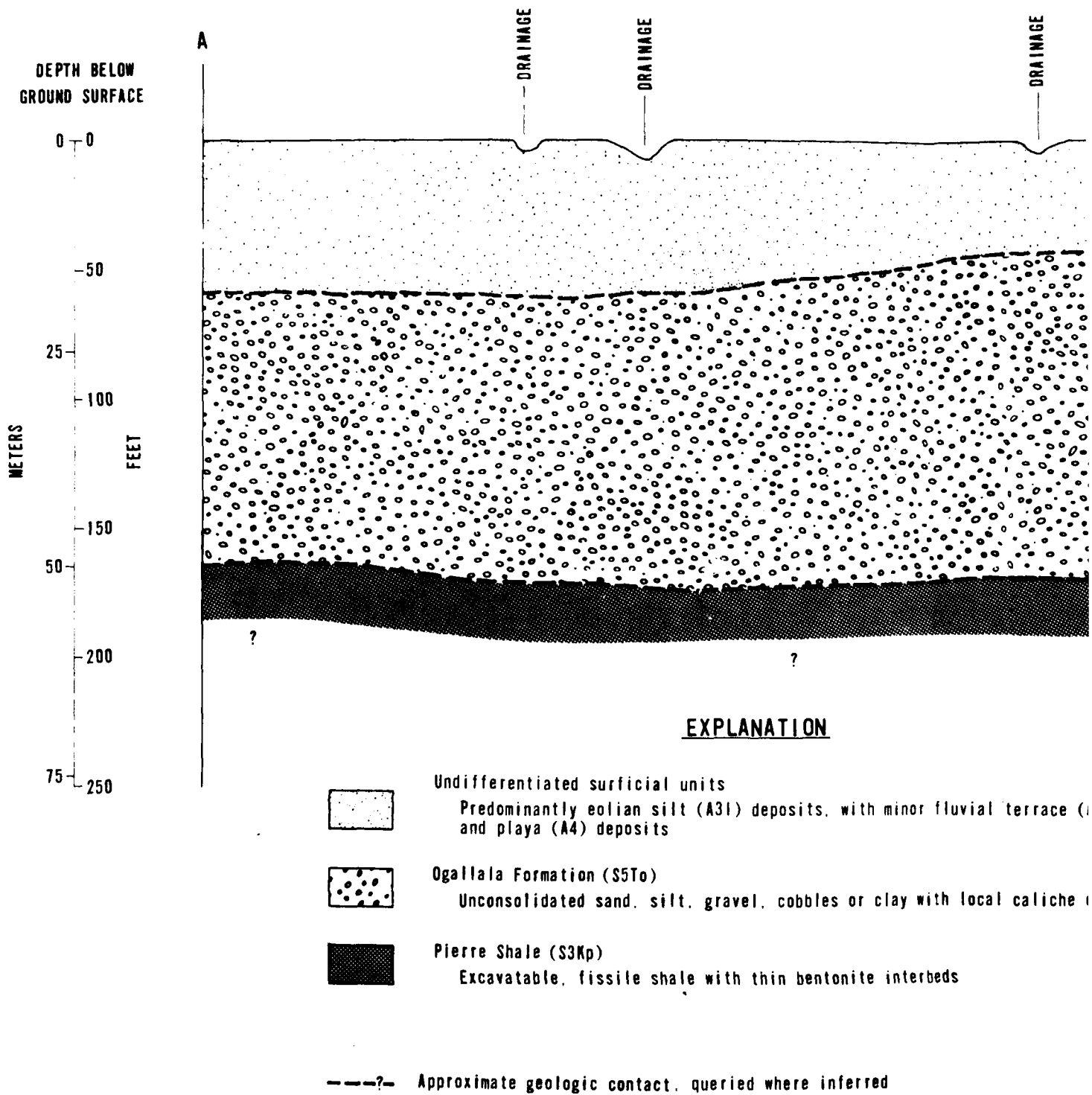
NOTE: For detailed description of geologic units, see Table A-1.

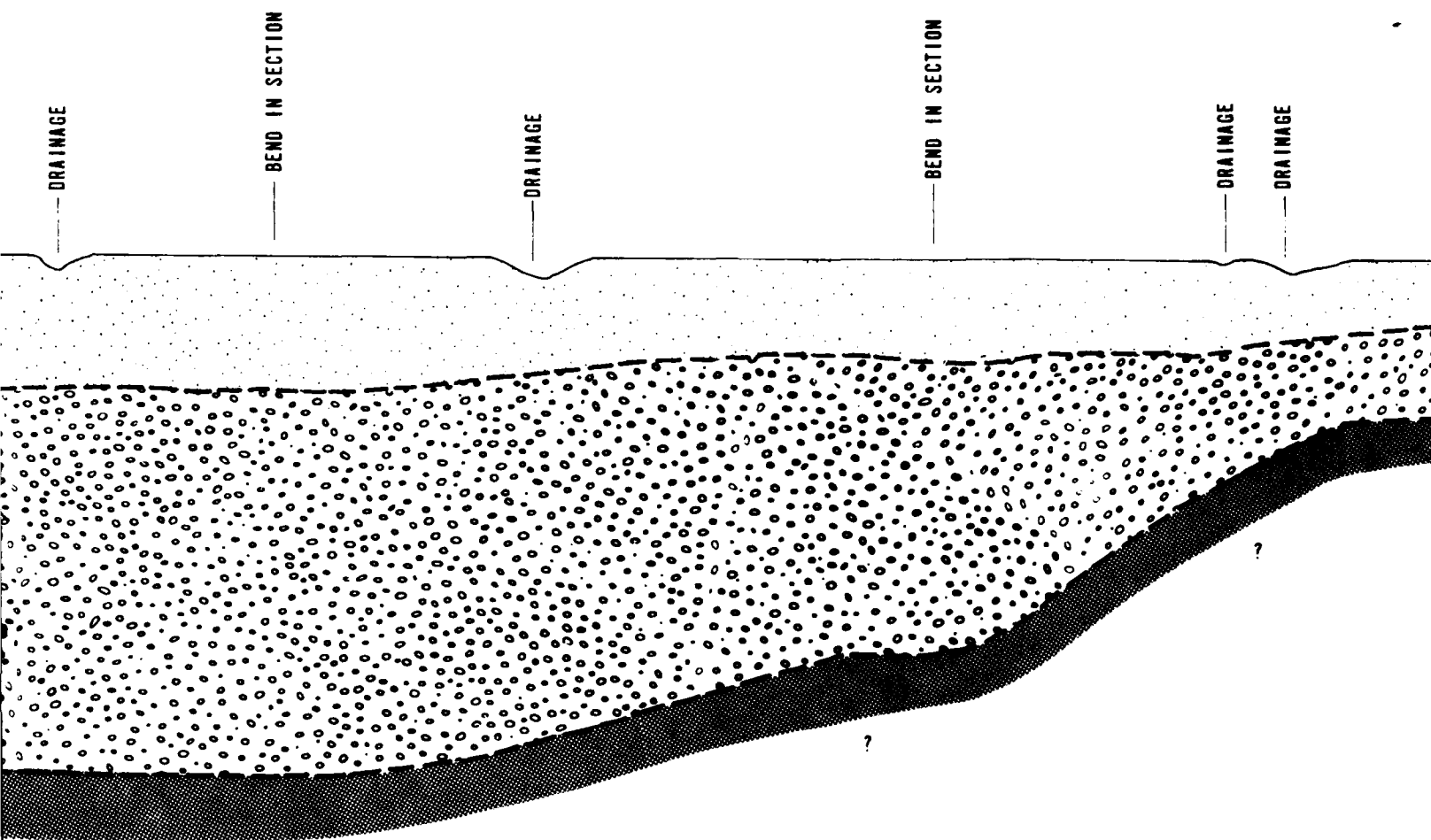
**GENERALIZED GEOLOGIC MAP AND
SELECTED SUBSURFACE FEATURES
SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP**

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
12

FUGRO NATIONAL, INC.



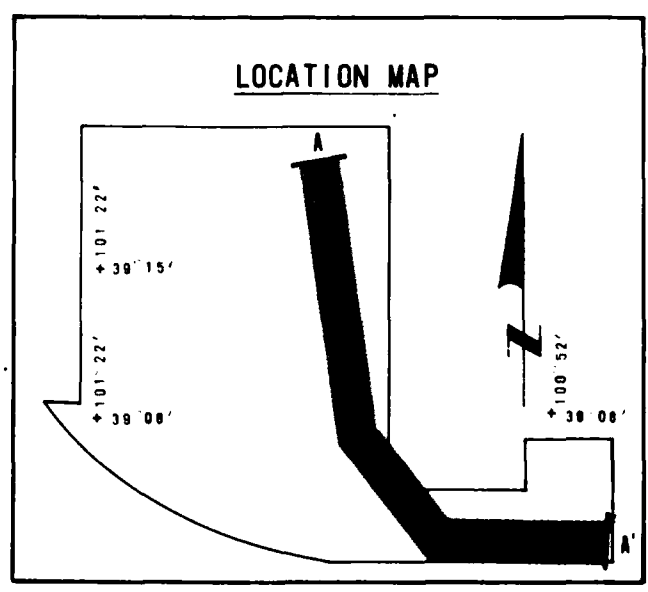


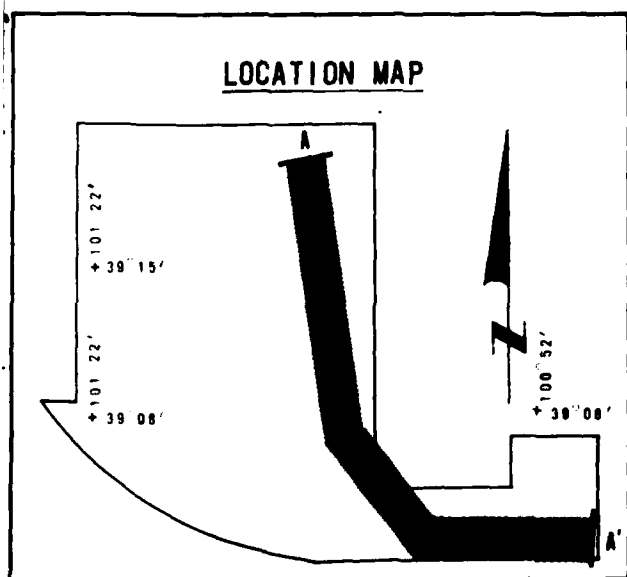
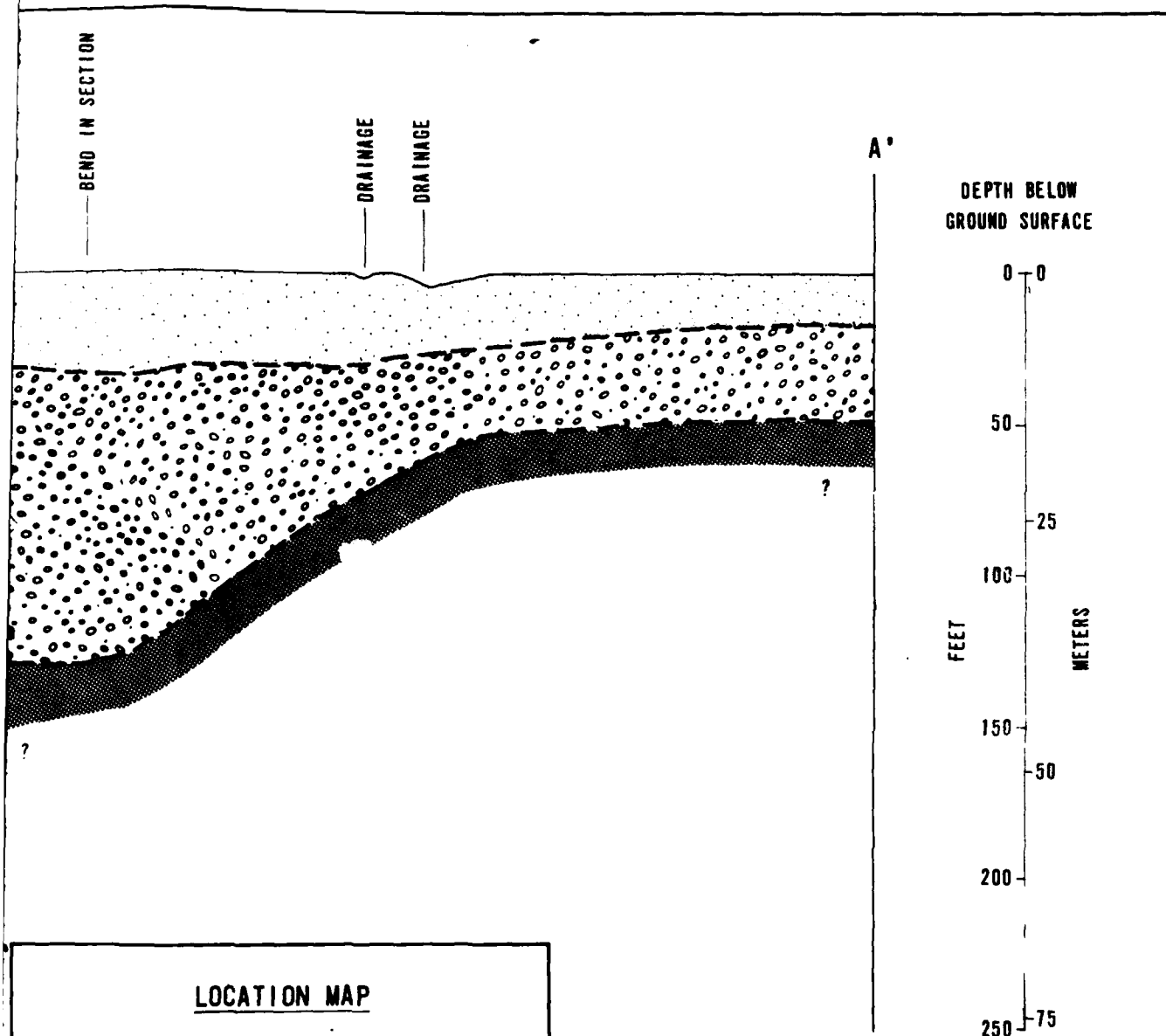
terrace (A1/A2)

caliche caprock

- NOTES: 1. Approximately 3000' (914m) of Mesozoic shale, limestone and sandstone underlie the Ogallala Formation (S5To)
2. The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.
3. For a detailed description of geologic units see Table A-1.

2

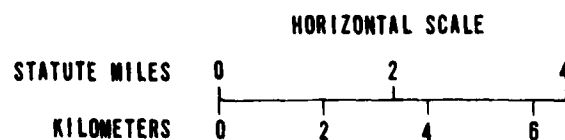




Horizontal Scale: 1" = 2 Miles (3km)

Vertical Scale: 1" = 50' (15m)

Vertical Exaggeration: 211X



**GENERALIZED GEOLOGIC CROSS SECTION
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP**

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
13

UBRO NATIONAL, INC.

3

3.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic and conductivity surveys are shown in Tables 12 and 13. In general, the results show the Scott City site to be fairly uniform both in velocities and average conductivity in the upper 50 feet (15 m).

The refraction lines did not indicate presence of a horizon with velocities greater than 7000 fps (2134 mps) in the upper 50 feet (15 m). Lines SY-S-6, 13, 18 and 20 detected a 7000 fps (2134 mps) layer at depths of 110, 70, 135 and 120 feet (34, 21, 41 and 37 m), respectively.

Average conductivities for the upper 50 feet (15 m) of the site soils are greater than the minimum value of 0.004 mhos/m specified in the Fine Screening criteria.

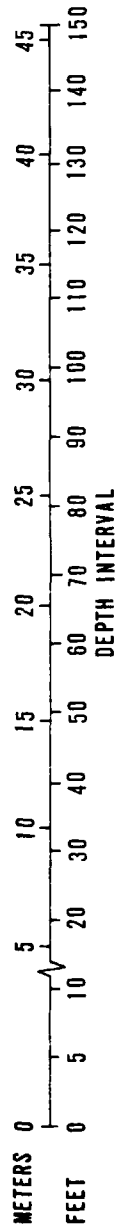
3.5 ENGINEERING PROPERTIES

Engineering properties of the subsoils were determined from laboratory tests. The tests consisted of: classification, consolidation, shear strength, compaction, CBR and chemical. The range of engineering and geophysical properties of the predominant geologic units at the Scott City site are summarized in Table 14.

The loess deposits are primarily formed of uncemented unsaturated poorly graded and slightly plastic clayey silt. They have a moderately high shear strength, are moderately compressible and are subject to limited structural collapse upon wetting.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)		DEEPER REFRACTORS DEPTH VELOCITY	* ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
SY-S-1	1100 (340)	2950 (900)	-	155 (47)
SY-S-2	1200 (370)	3200 (980)	-	154 (47)
SY-S-3	1180 (360)	3330 (1010)	-	142 (43)
SY-S-4	1150 (350)	3600 (1100)	-	119 (36)
SY-S-5	1170 (360)	2550 (780)	4820 (1470)	189 (58)
SY-S-6	1180 (360)	2520 (770)	7220 (2200)	-
SY-S-7	1210 (370)	2700 (820)	-	150 (46)
SY-S-8	1200 (370)	2500 (760)	3150 (960)	158 (48)
SY-S-9	1180 (360)	3350 (1020)	6300 (1920)	116 (35)
SY-S-10	1200 (370)	2300 (700)	3700 (1130)	171 (52)
SY-S-11	1200 (370)	2800 (850)	5850 (1780)	170 (52)
SY-S-12	1150 (350)	3800 (1160)	6250 (1900)	153 (47)
SY-S-13	(a) 1500 (460)	4000 (1220)	7700	-
SY-S-14	1250 (380)	2100 (640)	4000 (2350)	104 (32)
SY-S-15	1150 (350)	3620 (1100)	-	147 (45)
SY-S-16	1150 (350)	3100 (940)	-	160 (49)
SY-S-17	1100 (340)	2650 (810)	5900 (1800)	144 (44)
SY-S-18	1100 (340)	1700 (520)	7800 (2380)	-
SY-S-19	1000 (300)	2000 (610)	3600 (1100)	151 (46)
SY-S-20	1200 (370)	3200 (975)	7000 (2130)	7000 (2130)

NOTE: (a) 700 (210)



* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS SCOTT CITY, KANSAS CENTRAL HIGH PLAINS CSP

WX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
12

FUGRO NATIONAL, INC.

ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos m)**
R-1	.044
R-2	.037
R-3	.041
R-4	.045
R-5	.044
R-6	.033
R-7	.049
R-8	.029
R-9	.039
R-10	.035
R-11	.041
R-12	.026
R-13	.016
R-14	.032
R-15	.022
R-16	.036
R-17	.039
R-18	.025
R-19	.018
R-20	.045

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP

WX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS

TABLE
13

FUGRO NATIONAL, INC.

ENGINEERING AND GEOPHYSICAL PROPERTIES		
	Eolian loess deposits (A31)	Ogallala formation (S5)
UNIFIED SOIL CLASSIFICATION SYMBOL(S)	ML, CL-ML, CL	SP, SW, SW-SH, SC, GW, G
GENERAL PROPERTIES		
DRY DENSITY pcf(kg m ³)	70-115 (1121-1842)	98-127 (1570-2034)
MOISTURE CONTENT (%)	8-25	2-17
DEGREE OF SATURATION (%)	20-97	9-97
SPECIFIC GRAVITY	2.65	2.67
DEGREE OF CEMENTATION	None to weak	Weak to strong
COMPRESSIONAL WAVE VELOCITIES fps(mps)	1000-1300 (305-396)	1700± (518±)
ELECTRICAL CONDUCTIVITY (mhos m)	.018-.053	.004-.023
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS >12 inches(30cm)	0	0
COBBLES 3 to 12 inches(8to 30cm)	0	0-5
GRAVEL	0	0-25
SAND	0-5	10-96
SILT AND CLAY	95-100	5-90
PLASTICITY DATA		
LIQUID LIMIT	27-47	DNA
PLASTICITY INDEX	2-24	DNA
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf(192kN/m ²) (%)	2-6	DNA
SWELL OR COLLAPSE UPON SATURATION (%)	0-3 (Collapse)	DNA
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION ksf(kN m ²)	0.3-5 (14-239)	DNA
CD TRIAXIAL COMPRESSION	c=0-0.7 ks. (34 kN m ²), $\phi = 26^{\circ}$ -33°	DNA
DIRECT SHEAR ksf(kN m ²)	0.7-5 (34-240)	DNA
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY pcf(kg m ³)	110-115 (1762-1842)	DNA
OPTIMUM MOISTURE CONTENT (%)	14-17	DNA
CBR AT 90% RELATIVE COMPACTION	4-6	DNA

DNA = DATA NOT AVAILABLE (INSUFFICIENT DATA OR TESTS NOT PERFORMED)

GEOLOGIC UNITS

gallala formation (S5To)	
SW. SW-SM. SC. GW. GP. ML	
98-127 (1570-2034)	
2-17	
9-97	
2.67	
Weak to strong	
1700+ (518*)	
.004-.023	
0	
0-5	
0-25	
10-96	
5-90	
DNA	
DNA	
DNA	
DNA	
DNA	
DNA	
DNA	
DNA	
DNA	
DNA	

2

RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
SCOTT CITY, KANSAS

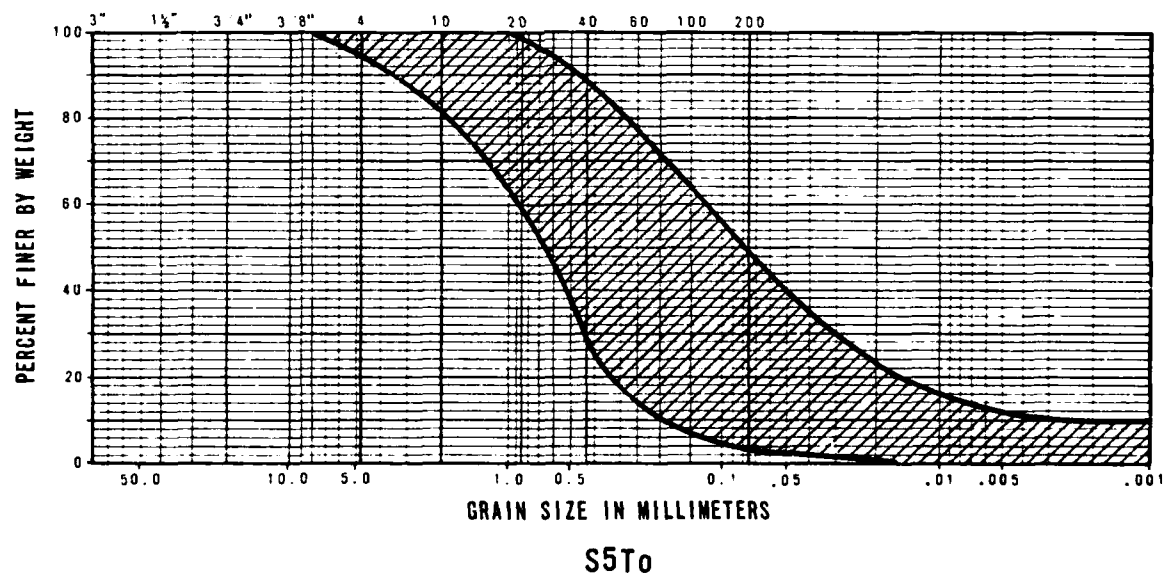
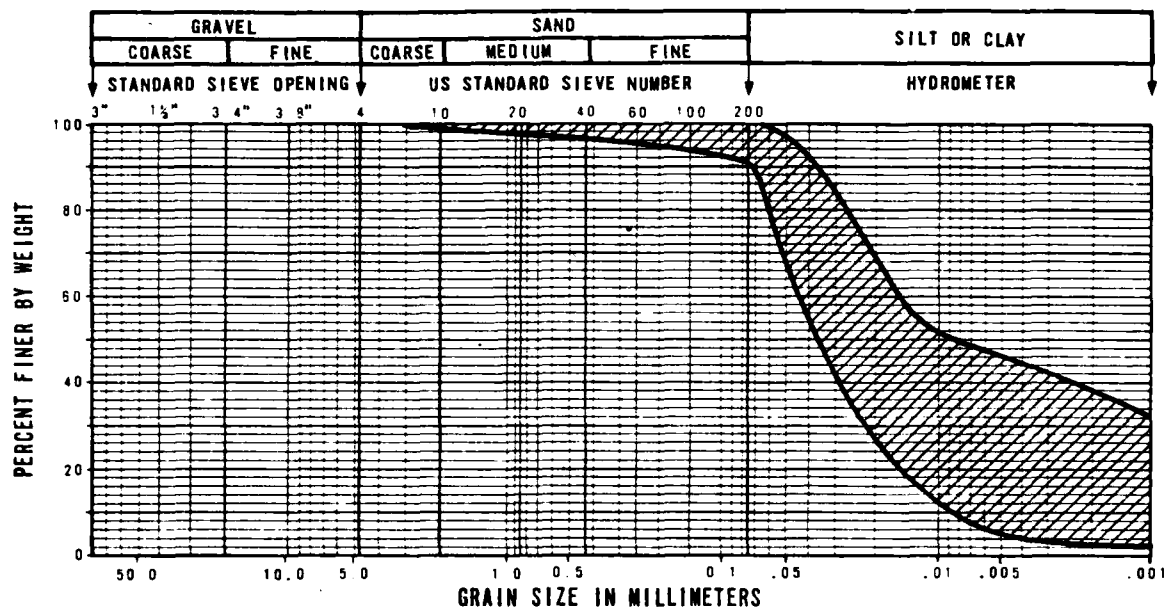
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
14

FUGRO NATIONAL, INC.

The Ogallala Formation is generally formed of uncemented, mostly unsaturated and well graded sands and silty sands with varying amounts of gravel and local caliche caprock. It has high shear strength and low compressibility. Range of gradation of the two geologic units is shown in Figure 14.

Representative logs of three borings and three trenches from the site are contained in Appendix C. Results of the shear strength, CBR, and chemical tests performed on soil samples from the site and a summary of all the laboratory tests performed on soil samples obtained from boring SY-B-6 are also included in Appendix C.



RANGE OF GRADATION OF GEOLOGIC UNITS
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
14

FUGRO NATIONAL, INC.

4.0 CIMARRON SITE

The Cimarron Characterization site covers an area of 505 nm² (1732 km²) in the northwestern Panhandle of Texas. The site is bounded by the Dallam-Hartley county line on the south, Oklahoma state line on the north, and state farm roads 807 and 1879 on the east and west, respectively. A network of paved and graded roads and four-wheel drive trails provide access within the site.

4.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site are presented in Table 15. Detailed information about the soils engineering field activities (18 borings and 18 trenches) is summarized in Tables 16 and 17. Locations of all the field activities are shown in Figure 15.

4.2 SURFICIAL GEOLOGY AND TERRAIN

Mixed windblown deposits are the predominant surficial geologic unit, covering approximately 80 percent of the Cimarron Characterization site (Figure 15). They are primarily composed of loess and sheet sands that are too interspersed to be separated into individual geologic units (Table 18). Interpretation of boring logs indicates that the thickness of this unit varies from approximately 50 to over 100 feet (15 to 30 m) across the site.

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological mapping stations	67
Shallow refraction	21
Electrical Conductivity	20

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
13	50 (15)
4	100 (30)
1	300 (91)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
4	6 (2)
11	10 (3)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	192
Sieve analysis	38
Hydrometer	27
Atterberg limits	22
Specific gravity	7
Consolidation	2

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	5
Triaxial compression	5
Direct shear	5
Compaction	3
CBR	3
Chemical Analysis	2

SCOPE OF FIELD AND LABORATORY
ACTIVITIES

CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSOTABLE
15**FUGRO NATIONAL, INC.**

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
CN-B-1	101.3 (30.9)	Rotary Wash	P
CN-B-2	51.0 (15.5)	Hollow Stem Auger	D, SS
CN-B-3	101.2 (30.8)	Rotary Wash	P
CN-B-4	51.0 (15.5)	Hollow Stem Auger	D
CN-B-5	300.5 (91.6)	Rotary Wash	P, D
CN-B-6	51.0 (15.5)	Hollow Stem Auger	D
CN-B-7	51.0 (15.5)	Hollow Stem Auger	D, P
CN-B-8	51.0 (15.5)	Hollow Stem Auger	D
CN-B-9	51.0 (15.5)	Hollow Stem Auger	D, P
CN-B-10	101.6 (31.0)	Rotary Wash	P, C
CN-B-11	50.5 (15.4)	Hollow Stem Auger	D, SS, P
CN-B-12	102.0 (31.1)	Rotary Wash	P
CN-B-13	51.0 (15.5)	Hollow Stem Auger	D
CN-B-14	51.0 (15.5)	Hollow Stem Auger	D
CN-B-15	50.9 (15.5)	Hollow Stem Auger	D, SS, B
CN-B-16	51.0 (15.5)	Hollow Stem Auger	D, SS
CN-B-17	51.0 (15.5)	Hollow Stem Auger	D
CN-B-18	51.0 (15.5)	Hollow Stem Auger	D

* P = Pitcher sample (undisturbed)

D = Fugro Drive sample (relatively undisturbed)

B = Bulk sample (disturbed, but representative)

SS = Split Spoon sample (disturbed, but representative)

C = Rock Core

ENGINEERING FIELD ACTIVITIES - BORINGS
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS

TABLE
16

FUGRO NATIONAL, INC.

TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
CN-T-1	10.8 (3.3)	Stable
CN-T-2	11.0 (3.4)	Stable, stage I caliche 5.5-11' (1.7-3.4m)
CN-T-3	9.4 (2.9)	Stable, stage I caliche 5.0-9.4' (1.5-2.9m)
CN-T-4	10.6 (3.2)	Stable, stage I caliche 6.0-10.6' (1.8-2.9m)
CN-T-5	6.6 (2.0)	Stable, stage I caliche 1.8-6.6' (0.5-2.0m); cementation at 6.6' (2.0m) exceeded capacity of backhoe*
CN-T-6	4.9 (1.5)	Stable, stage III caliche 3.8-4.9' (1.2-1.5m) cementation at 4.9' (1.5m) exceeded capacity of backhoe*
CN-T-7	10.5 (3.2)	Stable, stage I caliche 4.5-10.5' (1.4-3.2m)
CN-T-8	7.7 (2.3)	Stable, stage III caliche 7.0-7.5' (2.1-2.3m); stage IV caliche 7.5-7.7' (2.3m); cementation at 7.7' exceeded capacity of backhoe*
CN-T-9	8.6 (2.6)	Stable, stage III caliche 8.0-8.6' (2.4-2.6m); cementation at 8.6' (2.6m) exceeded capacity of backhoe*
CN-T-10	11.0 (3.4)	Stable, stage I caliche 0-1.4' (0.4m) and 2.6-11.0' (0.8-3.4m)
CN-T-11	3.5 (1.1)	Stable, stage III to stage IV caliche below 3.5' (1.1m) exceeded capacity of backhoe*
CN-T-12	11.4 (3.5)	Stable, stage I caliche 4.5-11.4' (1.4-3.5m)
CN-T-13	11.8 (3.6)	Stable, stage I caliche 4.0-11.8' (1.2-3.6m)
CN-T-14	8.7 (2.6)	Stable, stage III caliche 8.4-8.7' (2.6m) exceeded capacity of backhoe*
CN-T-15	11.2 (3.5)	Stable, stage III caliche at 11.2' (3.5m)
CN-T-16	10.2 (3.1)	Stable, stage I caliche 7.5-10.2' (2.3-3.1m)
CN-T-17	11.2 (3.4)	Stable, stage I caliche 1.0-11.2' (0.3-3.4m)
CN-T-18	7.2 (2.2)	Stable, stage III to stage IV caliche at 7.2' (2.2m) exceeded capacity of backhoe*

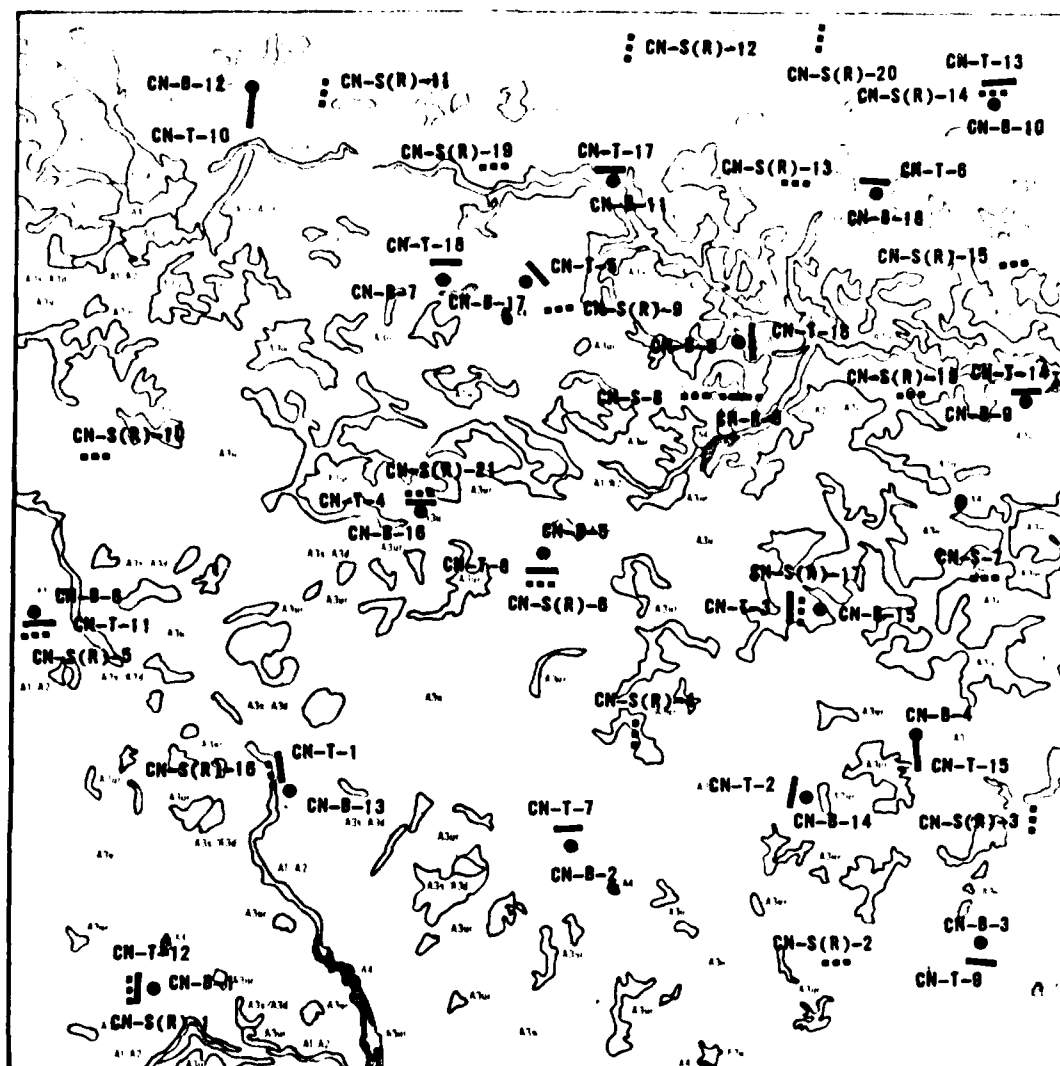
*Case 580C

ENGINEERING FIELD ACTIVITIES - TRENCHES
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

TABLE
17

FUGRO NATIONAL, INC.



EXPLANATION

SURFICIAL GEOLOGIC UNITS

- A1 A2 and A3 - stream channel terrace and eolian deposits
- A4 - playa deposits

SYMBOLS

- Boring
- Shallow Seismic Refraction Line
- Resistivity (Conductivity) Line
- S(R) Both Shallow Seismic and Resistivity Line
- Trench

NOTE: For detailed description of geologic units, see Table A-1.

GENERALIZED GEOLOGIC MAP AND
FIELD ACTIVITY LOCATIONS
CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP

WY SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSOC

FIGURE
15

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Resistant units cover approximately 13 percent of the site and consist of well developed near surface (<16 inches; <41 cm) pedogenic calcic horizons (Stage IV). The deposit is lensed and discontinuous, typically 1.5 feet (0.5 m) thick but ranges in thickness up to eight feet (2.5 m).

Fluvial and sand dune deposits comprise six percent of the site area and are generally of importance only in the southwestern portion of the site. The remaining one percent of the site consists of fluvial, stream terrace and playa deposits primarily consisting of sands, silts and clays. Discontinuous thin lenses of sandy gravel are also associated with the fluvial and terrace deposits.

The site slopes to the east at a general gradient of 0.3 percent. Local relief generally averages less than ten feet (3 m) per half mile. The predominant surficial deposit (mixed wind-blown silts and sands) forms zero to three percent slopes. Drainage channels are widely spaced and average approximately 30 feet (10 m) in depth. They generally range from 0.2 to 0.9 nm (0.4 to 1.7 km) in width, with an average of 0.25 nm (0.4 km). Stream bank slopes average from 3 to 35 percent slope. A summary of the soil and terrain conditions for each surficial geologic unit is shown in Table 18.

4.3 SUBSURFACE CONDITIONS

4.3.1 Soil Profiles

The composition of soils with depth is illustrated by the soil profiles shown in Figures 16 and 17. The predominant

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S) (b)	AREAL EXTENT (SITE)		
					nm ² (km ²)	PERCENT	
Fluvial and Stream Terrace Deposits (A1 A2 Au)	Quaternary	5-40 (2-12)	Clayey Silty Sands	SM	5 (17)	1	
Sheet and Dune Sands (A3s A3d)	Quaternary	10-15 (3-5)	Silty Sand	SM	30 (103)	6	
Undifferentiated Eolian Deposits (A3u)	Quaternary	40-100 (12-30)	Clayey Silty Sand	SM	404 (1382)	80	
Resistant Areas (A3ur)	Quaternary	2-12 (1-4)	Caliche Horizon	-	66 (226)	13	
Playa Deposits (A4)	Quaternary	2-15 (1-5)	Sandy Silty Clay	CL	<5 (<17)	<1	
Ogallala Formation (S5To)	Pliocene	> 200 (> 60)	Clayey Silt to Gravel	ML-GP	-	-	

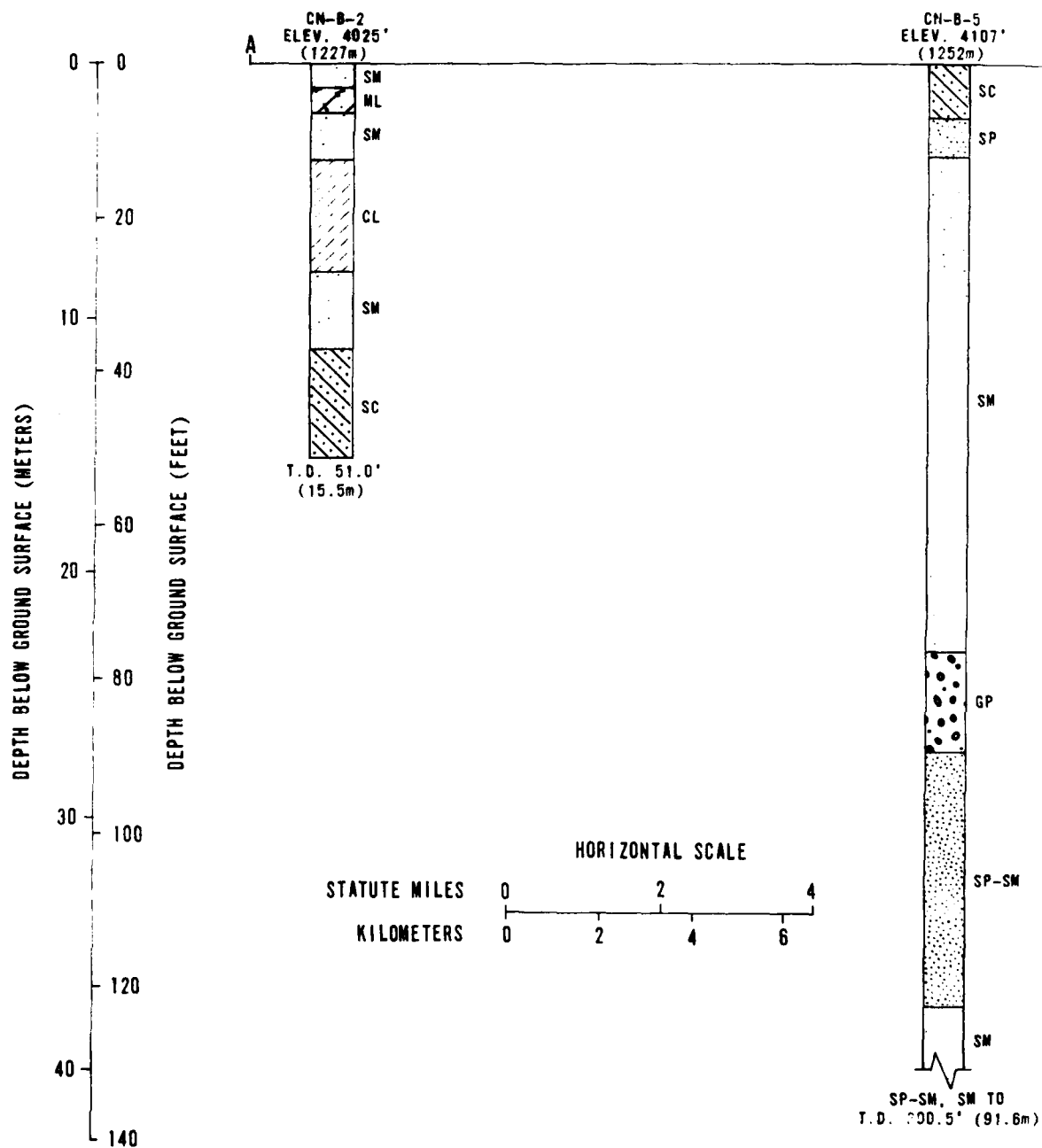
NOTES:

- (a) For generic description of geologic units, see Table A-1.
 (b) For description of USCS symbols, see Table A-2.
 (c) For description of stage of caliche, see Figure A-1.
 (d) Geologic unit underlies the site at depths ranging from 20 to >50 feet.

AREAL EXTEN. (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
nm ² (km ²)	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/ PATINA	STAGE OF CALICHE (c)	SLOPE (PERCENT)	DRAINAGE DEPTHS FEET (METERS)	
5 (17)	1	Poor-Well	Weak	Cobble	Not Applicable	I	3-35	5-60 (2-18)	
30 (103)	6	Poor-Well	Weak	Sand	Not Applicable	I	0-10	5-40 (2-12)	
404 (1382)	80	Poor-Well	Weak-Strong	Sand	Not Applicable	I-IV	0-3	5-40 (2-12)	
66 (226)	13	-	Strong	-	Not Applicable	II	0-5	5-20 (2-6)	
<5 (<17)	<1	Poor	None	Sand	Not Applicable	None	0-1	10-30 (3-10)	
-	-	Poor-Well	Weak-Strong	Cobble	Not Applicable	I-IV	-	-	(d)

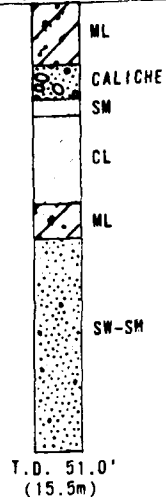
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DESCRIPTION OF SURFICIAL GEOLOGIC UNITS CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMSO	TABLE 18
FUGRO NATIONAL, INC.	

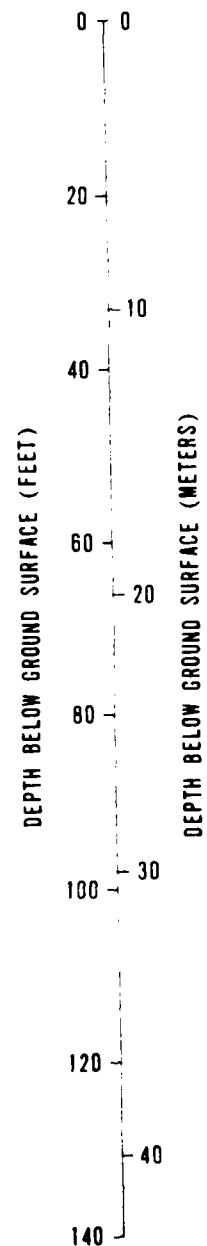
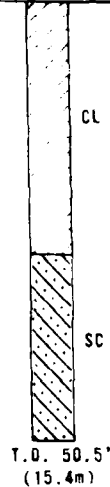


- NOTES:
1. Ground surface elevations shown at locations of borings are
 2. T.D. = Total Depth
 3. Soil types shown adjacent to soil column are based on Unifie (USCS) and are explained in the appendix

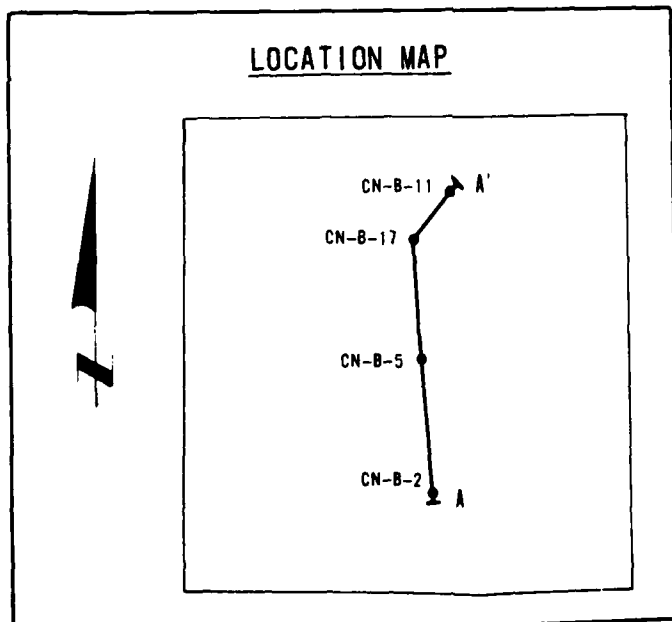
CN-B-17
ELEV. 4094'
(1248m)



CN-B-11
ELEV. 4043'
(1232m) A'

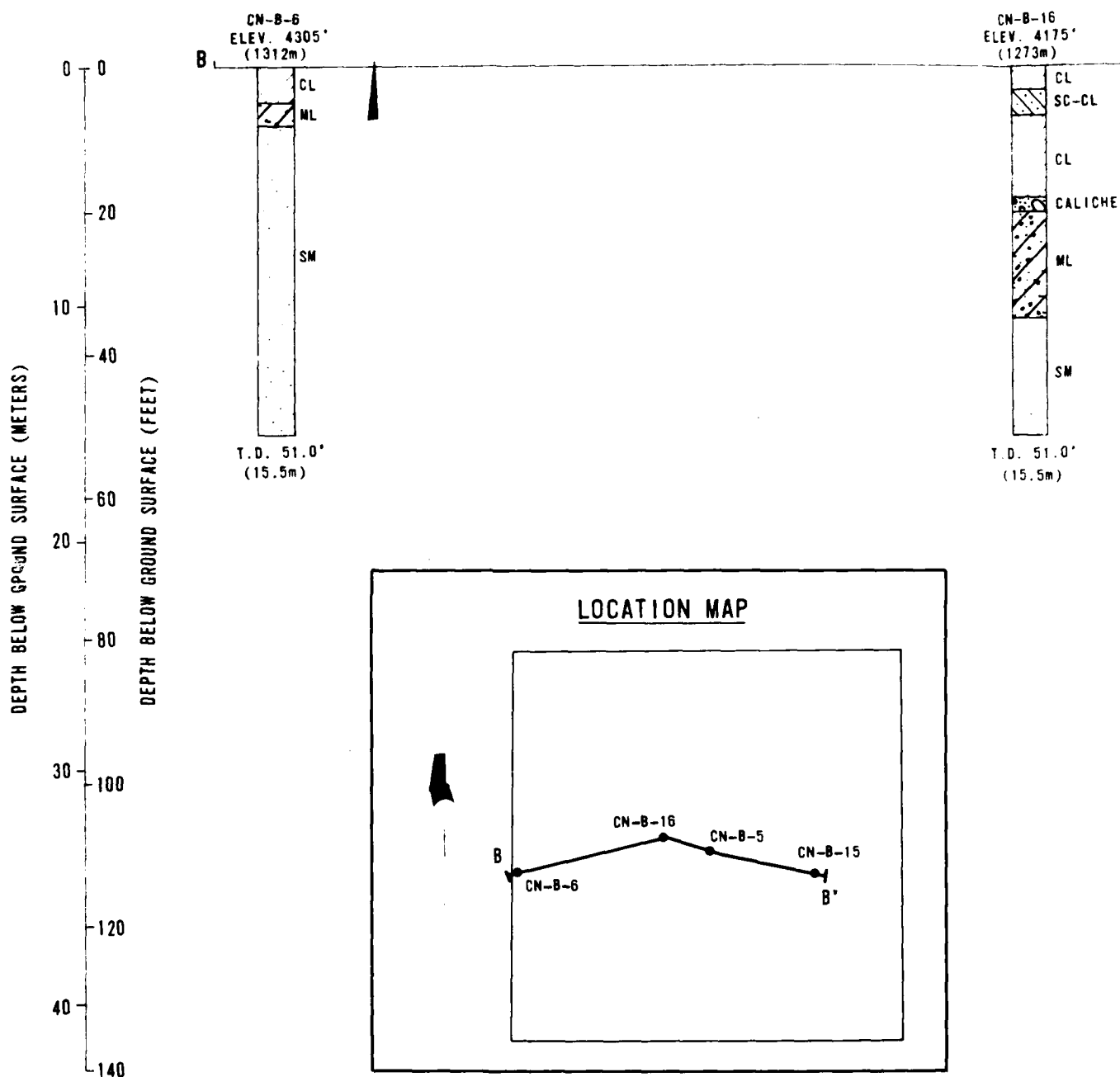


LOCATION MAP

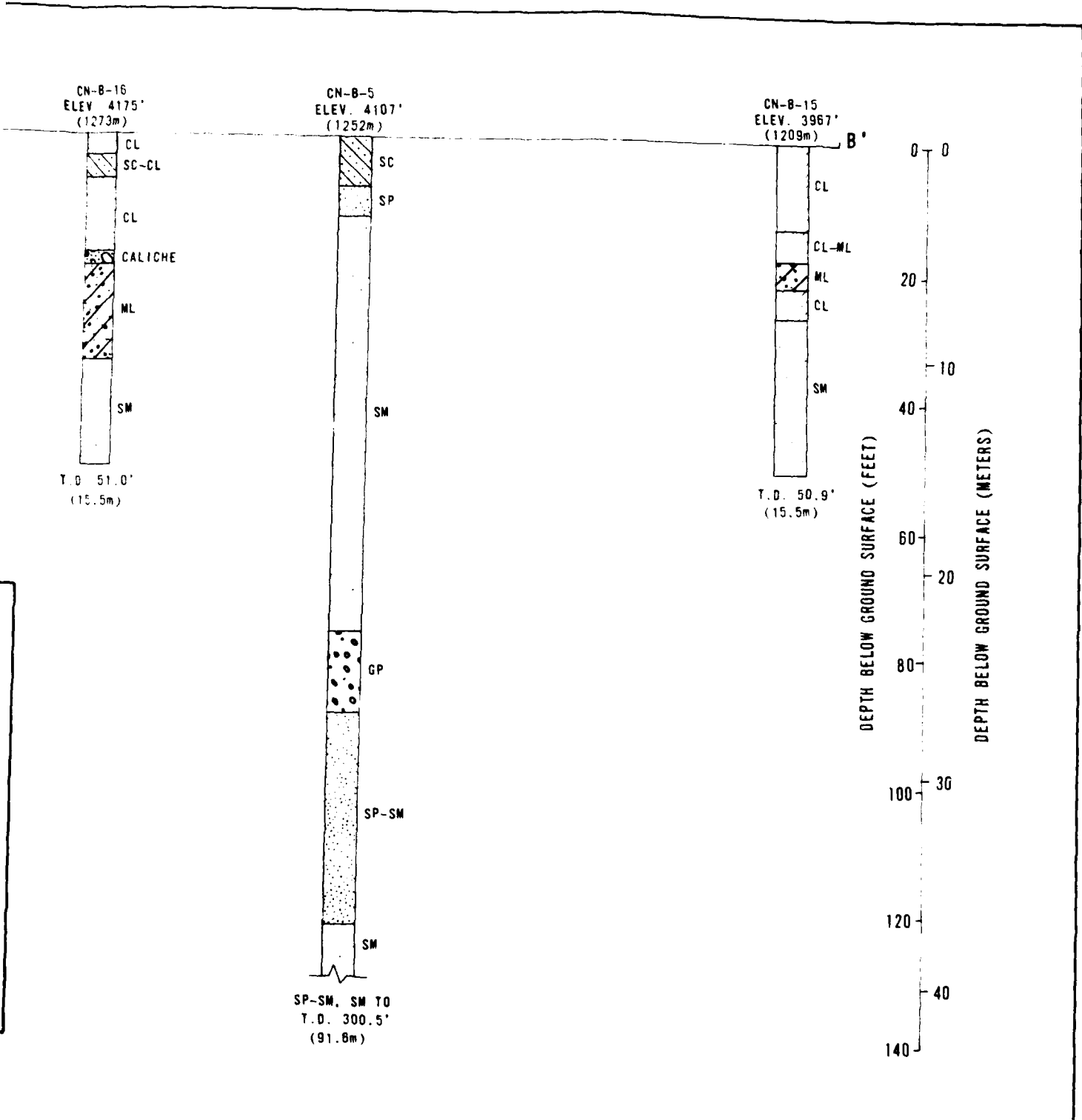


2

SOIL PROFILE AA' CIMARRON, TEXAS CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	SAMSO
FIGURE 16	
FUGRO NATIONAL INC.	



- NOTES: 1. Ground surface elevations shown at locations of borings are approximate
 2. T.D.= Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix



ion System

2

SOIL PROFILE BB' CIMARRON, TEXAS CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMSQ	FIGURE 17
FUGRO NATIONAL, INC.	

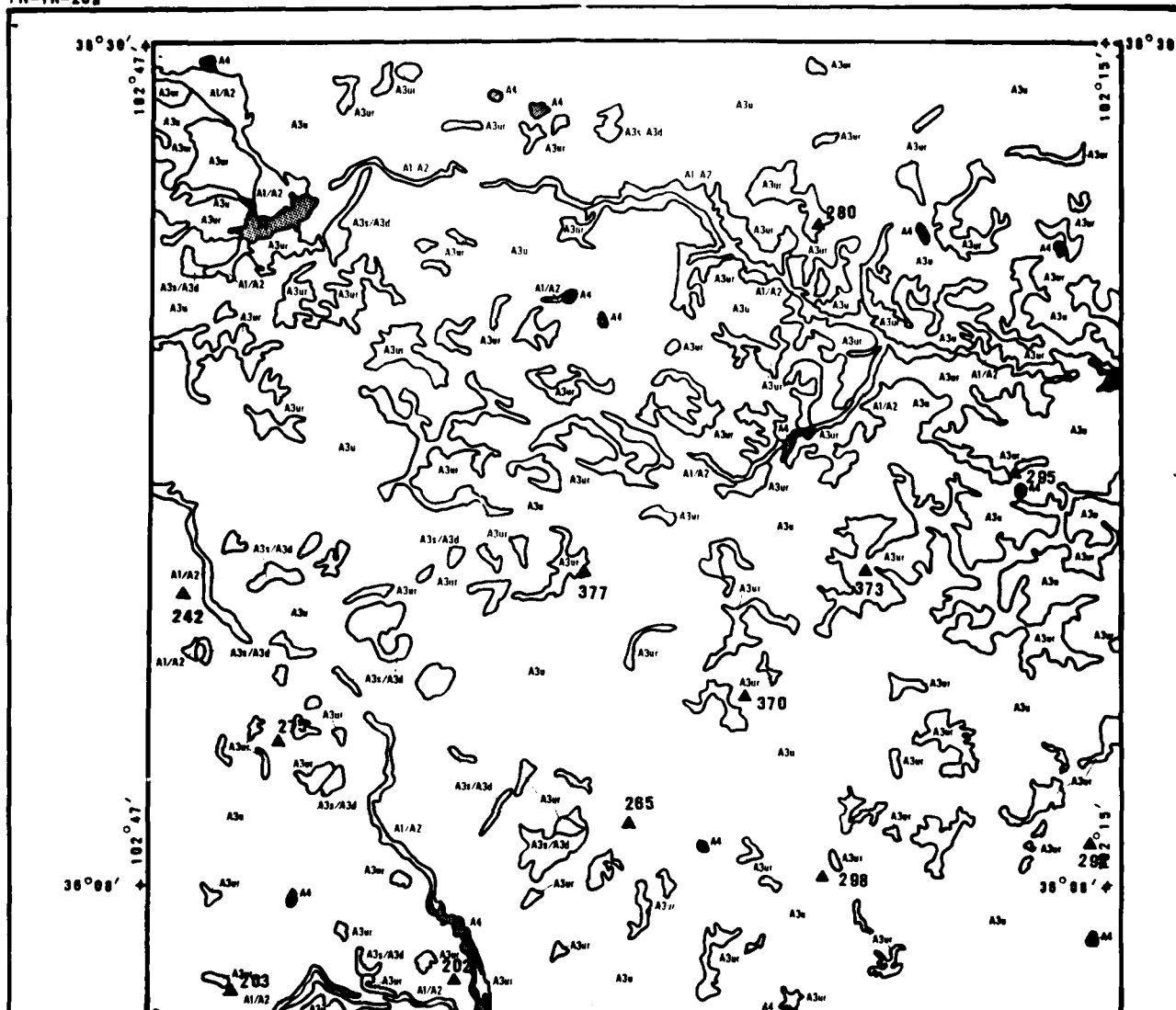
surficial geologic units are mixed windblown deposits (A3s and A3l) consisting of sand (SM, SP) and clays and silts (CL, ML). They are underlain by the Ogallala Formation (S5To) consisting predominantly of poorly graded sands (SM, SC, SP), at depths ranging from 40 to 85 feet (12 to 26 m)

4.3.2 Depth To Shallow (<150 Feet; <46 m) Rock and Water

Unexcavatable rock occurs at depths in excess of 800 feet (300 m). Figure 18 shows that depth to water is greater than 200 feet (61 m) in all areas, averaging about 280 feet (95 m). A generalized geologic cross section of the site is presented in Figure 19.

4.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic and conductivity surveys are shown in Tables 19 and 20, respectively. Although a surface layer (1000-2000 fps; 305-610 mps) is present at most locations, the velocities of the underlying layers vary from 2100 to 10,000 fps (640 to 3048 mps). Borings were located at three of the six locations where bedrock velocities (>7000 fps; >2134 mps) were observed within 30 feet (9 m) of the surface; caliche horizons corresponded to the high bedrock velocities in these borings. Average conductivities for the upper 50 feet (15 m) ranged from 0.001 to 0.056 mhos/m, and conductivities at two locations were less than the minimum of 0.004 mhos/m specified in the Fine Screening criteria.



EXPLANATION

SURFICIAL GEOLOGIC UNITS

- A1/A2 and A3 - fluvial/terrace and eolian deposits
- A4 - playa deposits

SYMBOLS

285 Depth to ground-water table in feet

Depth to excavatable rock is >400 feet
Depth to rock is >800 feet

1:300,000

1" = 5 MILES

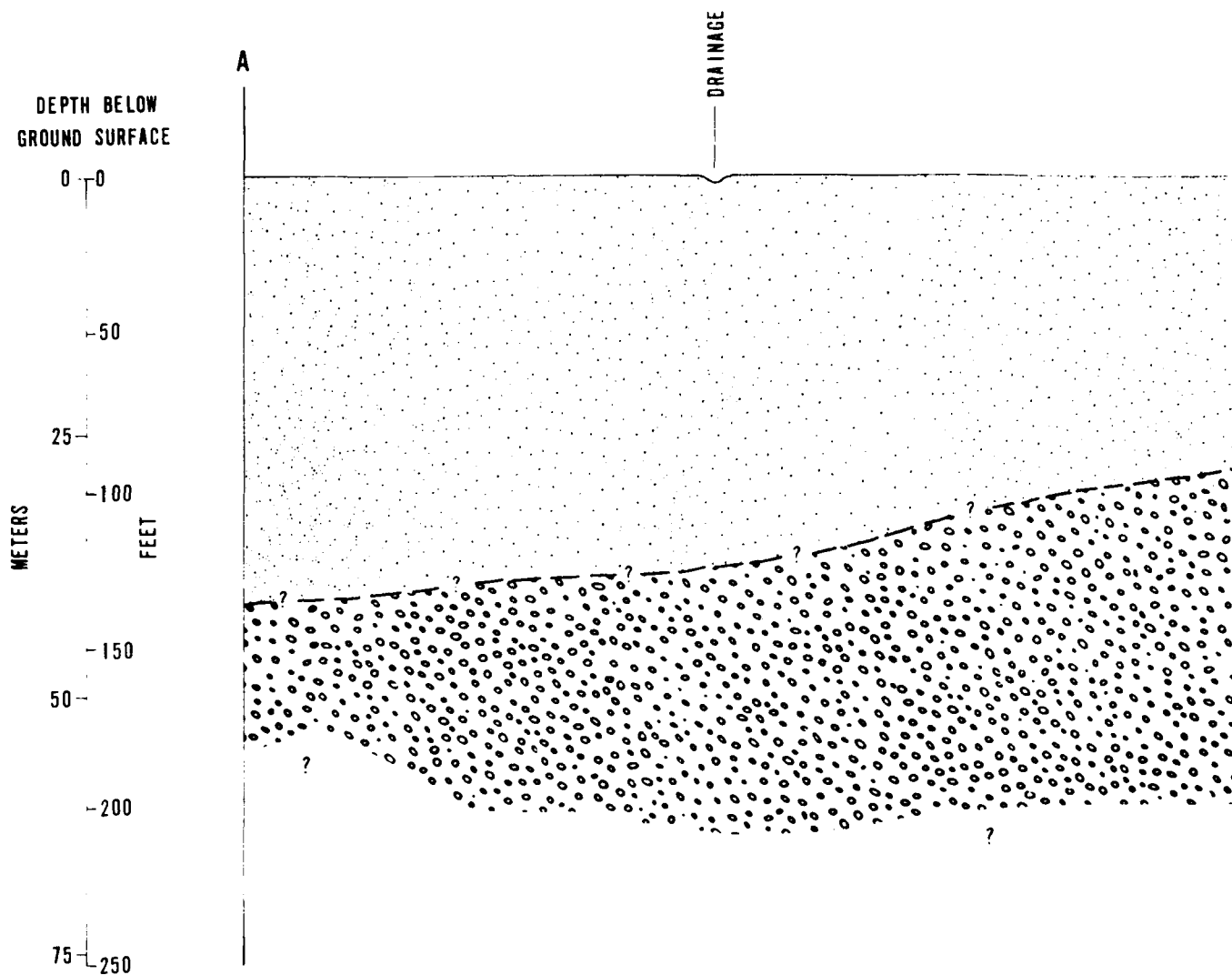
NOTE: For detailed description of geologic units, see Table A-1.

GENERALIZED GEOLOGIC MAP AND
SELECTED SUBSURFACE FEATURES
CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP




MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

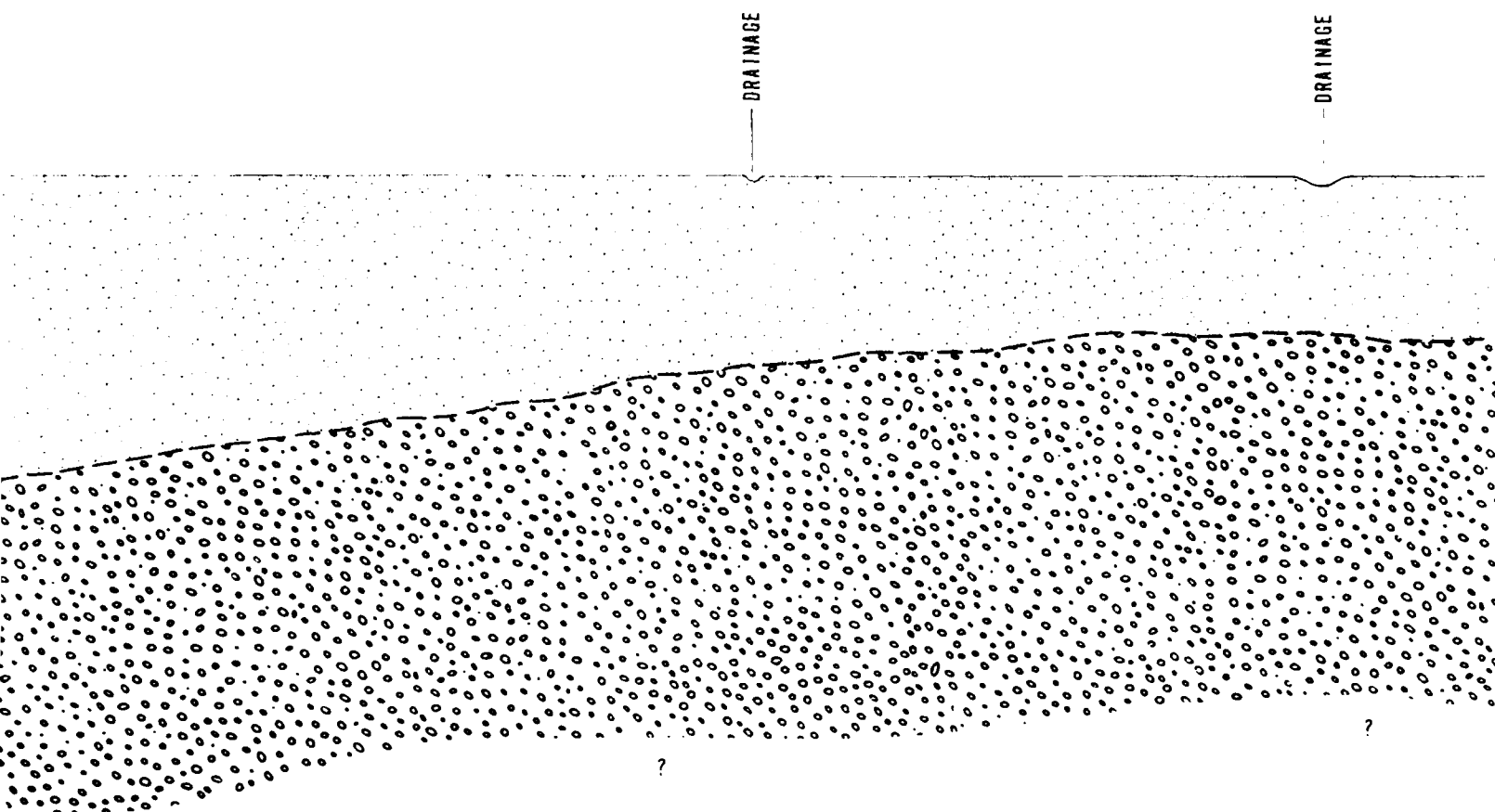
FIGURE
18

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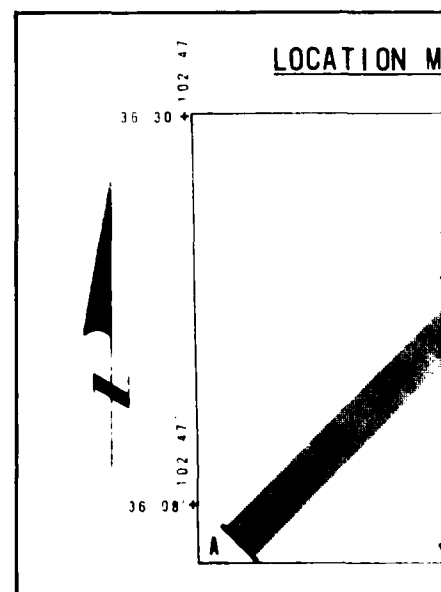
EXPLANATION

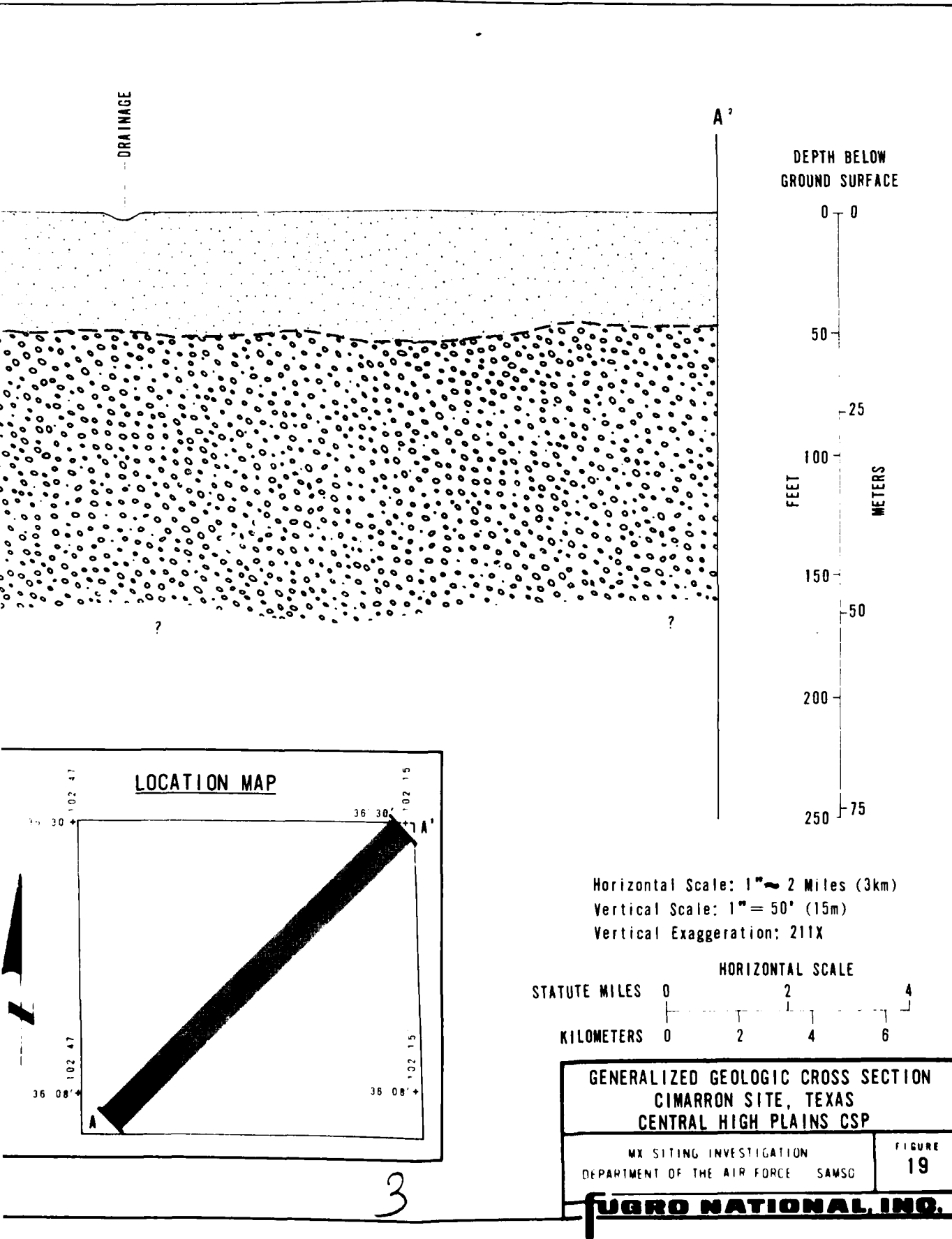
-  Undifferentiated surficial units
Predominantly eolian (A3) deposits with (A1 A2) and playa (A4) deposits
-  Ogallala Formation (S5To)
Unconsolidated sand, silt, gravel, cobbl with local caliche caprock
-  Approximate geologic contact, queried where

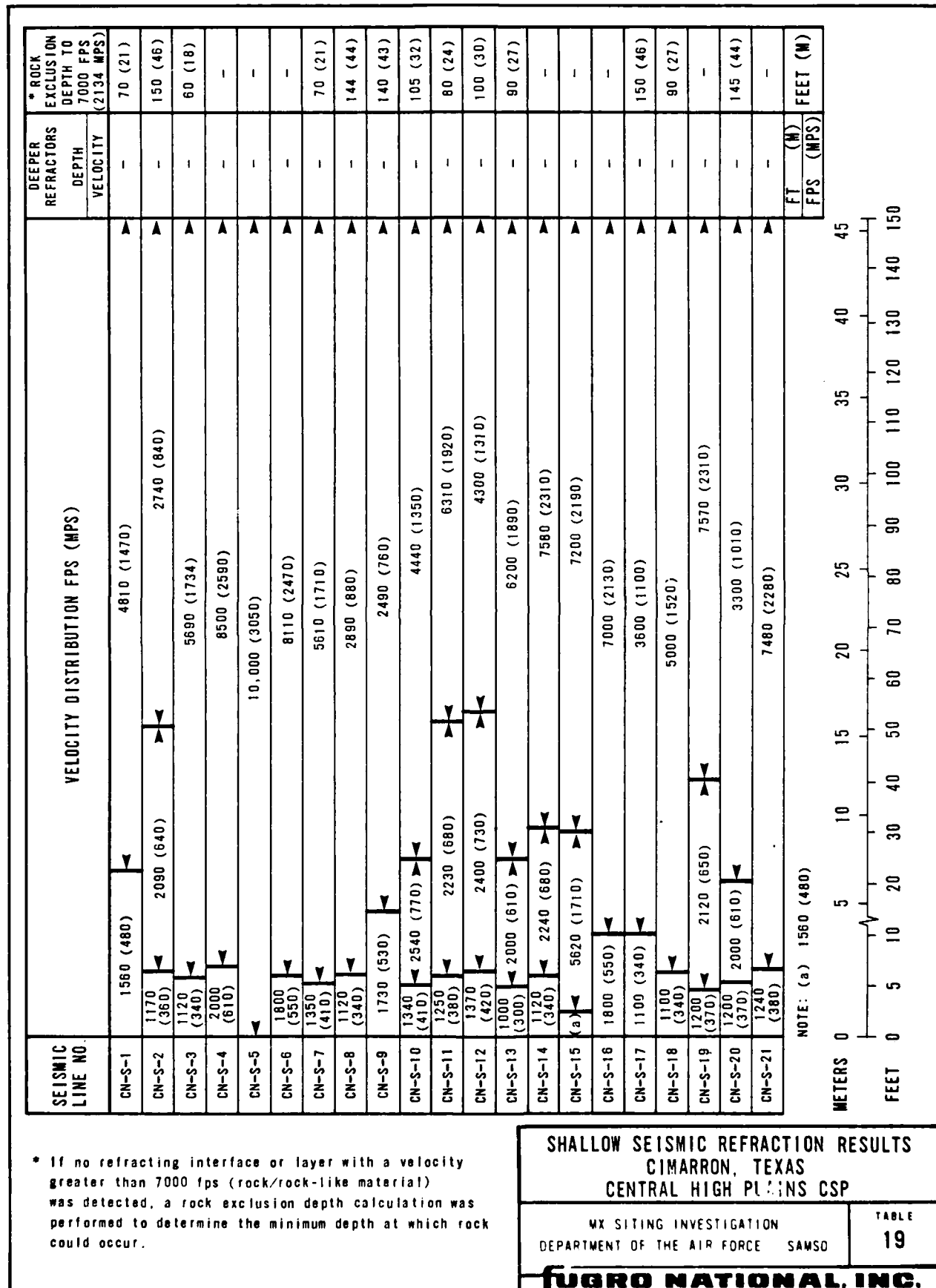


minor fluvial terrace

- NOTES: 1. The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.
2. For a detailed description of geologic units see Table A-1.







ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos m)**
R-1	.030
R-2	.053
R-3	.021
R-4	.010
R-5	.001
R-6	.004
R-7	-
R-8	.027
R-9	.045
R-10	.022
R-11	.035
R-12	.034
R-13	.056
R-14	.026
R-15	.007
R-16	.011
R-17	.025
R-18	.023
R-19	.030
R-20	.030
R-21	.013

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

VX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
20

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4.5 ENGINEERING PROPERTIES

Engineering properties of the subsoils were determined from laboratory tests. The tests consisted of: classification, consolidation, shear strength, compaction, CBR and chemical. The range of engineering and geophysical properties of the predominant geologic units at the Cimarron site is summarized in Table 21.

Mixed windblown deposits consist of sands, clays and silts. They are weakly to moderately cemented and have a moderately high shear strength. The soils have a low to moderate compressibility and could be locally collapsible upon wetting.

The Ogallala Formation is generally formed of weakly cemented, poorly graded fine to medium sands and silty sands which have moderately high shear strength and low compressibility.

The site soils are generally not expansive. Range of gradation of the two geologic units is shown in Figure 20.

Representative logs of three borings and three trenches from the site are contained in Appendix D. Results of the shear strength, CBR, and chemical tests performed on soil samples from the site and a summary of all the laboratory tests performed on soil samples obtained from boring CN-8-5 are also included in Appendix D.

ENGINEERING AND GEOPHYSICAL PROPERTIES		A3u
UNIFIED SOIL CLASSIFICATION SYMBOL(S)		SP, SC, SM, SW, CL, ML, CH
GENERAL PROPERTIES		
DRY DENSITY	pcf(kg m ³)	90-120 (1442-1922)
MOISTURE CONTENT	(%)	2-20
DEGREE OF SATURATION	(%)	25-98
SPECIFIC GRAVITY		DNA
DEGREE OF CEMENTATION		Weak to Moderate
COMPRESSIONAL WAVE VELOCITIES	fps(mps)	1100-2800 (335-853)
ELECTRICAL CONDUCTIVITY	(mhos m)	0.012-0.083
GRAIN SIZE DISTRIBUTION	(%)	
BOULDERS >12 inches (30cm)		0
COBBLES 3 to 12 inches (8 to 30cm)		0
GRAVEL		0-26
SAND		0-80
SILT AND CLAY		20-87
PLASTICITY DATA		
LIQUID LIMIT		21-45
PLASTICITY INDEX		NP-30
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf (192 kN m ²)	(%)	1-2.5
SWELL OR COLLAPSE UPON SATURATION	(%)	0-.2 Swell
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION	ksf(kN m ²)	0.5-5 (24-239)
CD TRIAXIAL COMPRESSION		C=0-2 (96) ϕ =28 -38
DIRECT SHEAR	ksf(kN m ²)	2.1-4.8 (101-153)
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY	pcf(kg m ³)	116-122 (1858-1954)
OPTIMUM MOISTURE CONTENT	(%)	9.5-14.5
CBR AT 90% RELATIVE COMPACTION		3-15

GEOLOGIC UNITS

	S5To
CH	SP, SW, SC, GW, GP
	100-120 (1602-1922)
	8-25
	35-90
	2.65-2.7
	Moderate
	5250 ± (1600 ±)
	0.003-0.071
	0
	0
	0-18
	37-98
	2-35
	DNA
	DNA
	DNA
	DNA
	DNA
8	DNA
	DNA
	DNA
	DNA
	DNA

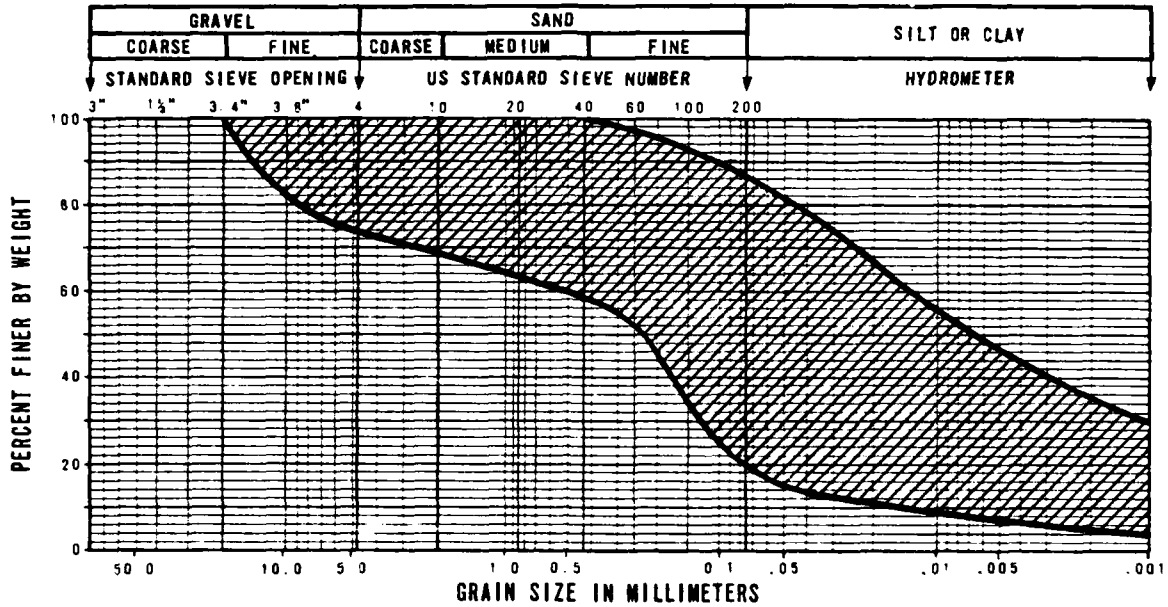
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RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP

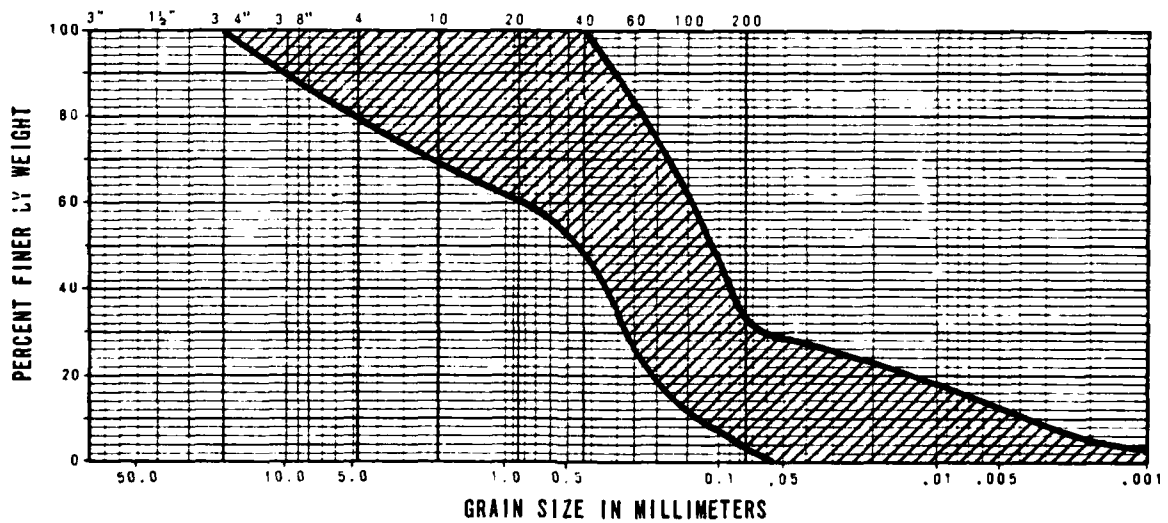
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSU

TABLE
21

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A3u



S5To

RANGE OF GRADATION OF GEOLOGIC UNITS
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
20

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5.0 DISCUSSION

Analysis of the data collected indicates similarities and differences in general geologic conditions between all three sites in the Central High Plains CSP. The apparent similarities are:

- o Silts and sands of either eolian or fluvial origins are the predominant surficial deposits.
- o The Ogallala Formation occurs at or near the surface (averages <50 feet; <15 m) in all three CSP sites. It consists of sands, gravels, silts and clays.
- o Terrain is nearly flat with local relief generally less than a few tens of feet per mile and slopes less than three percent. Widely spaced (>5 nm; >9 km), broad (0.25-0.5 nm; 0.45-0.93 km) ephemeral stream drainages are commonly 20 to 40 feet (6 to 12 m) deep and contain stream banks with slopes from three to 18 percent.
- o Depth to ground water averages between 140 and 200 feet (42 and 60 m).
- o Rocks units within the construction zone of up to 150 feet (46 m) are "excavatable". They consist primarily of shale and have associated seismic velocities greater than 7000 ft/sec (2121 m/sec).
- o Compressional wave velocities in the construction zone (150 ft; 46 m) generally range between 1000 and 6000 fps (305 to 1830 mps). However, frequent occurrence of velocities greater than 7000 fps (2134 mps) can be expected to occur within the construction zone in caliche horizons.

Dissimilarities between the sites are:

- o Greater proportion of surficial sand units in the Cimarron and Sterling sites, with average grain size and extent generally increasing from north to south between these two sites.
- o Depth to excavatable rock averages greater than 400 feet (121 m) in the Cimarron site, greater than 200 feet (61 m) in the Sterling site, and approximately 150 feet (45 m) in the Scott City site.
- o Discontinuous caliche horizons are of greatest significance in the Cimarron site, covering 13% of the area. They are also of significance in the Sterling site and are of little significance in the Scott City site.

Based on regional geologic information, geotechnical conditions of the Sterling City site are representative of approximately 27 percent of the CSP primarily within Nebraska and Colorado. Scott City typifies approximately 26 percent of the CSP predominantly in Kansas and east-central Colorado. Although Cimarron characterizes the smallest portion of the CSP (14 percent) it typifies the great diversity of geologic conditions presented in the southern portion of the province. The remaining 33 percent of the CSP represents a variety of geotechnical conditions similar to but not typical of any of the three sites.

6.0 CONSTRUCTION CONSIDERATIONS

In this section geotechnical factors and conditions applicable to construction of the MX System are discussed. The three basing mode concepts considered are vertical shelter, in-line hybrid trench, and horizontal shelter.

The important geotechnical factors for a vertical shelter are roads (primary, secondary and interconnecting), drainage crossings, and excavation of shelters. For the in-line hybrid trench, important geotechnical factors are excavation and back-fill, roads (primary, secondary and temporary), drainage crossings, and aggregates for roads and concrete. For the horizontal shelter, roads and drainage crossings are the important geotechnical factors. A brief summary of the applicable geotechnical factors is presented in the following paragraphs.

- o Terrain - The terrain is generally flat with local relief of a few feet per mile and slopes generally less than three percent thus requiring little preconstruction grading for roads and MX trenches. Drainage incisions are widely spaced and depths range from 20 to 40 feet (6 to 12 m) at the Sterling site, 20 to 30 feet (6 to 9 m) at the Scott City site and 30 to 60 feet (9 to 18 m) in Cimarron site. Due to wide spacing of the drainage incisions, total cost of drainage structures for roads and trenches will not be significant.
- o Roads - A network of unpaved farm roads exists over most of the area in all the three sites, minimizing the need for new secondary roads. However, new primary and inter-connecting roads will be required.

In the Sterling and Cimarron sites, more than 55 percent of the surficial deposits consist of fine-grained soils. In Scott City site, more than 85 percent of the surficial soils are fine-grained. These fine-grained soils are marginally suitable as road subgrade. They have relatively low bearing strength requiring thick roadway sections. To support the heavy loads of an MX transporter (in case of vertical and horizontal shelter mode), either base course material will have to be imported or soil improvement techniques will have to be used. Both these procedures are expensive, thus increasing road construction costs.

- o Excavation - Most of the subsurface soils are weakly to moderately cemented and possess moderate to moderately high shear strength. Compressional wave velocities range from 800 to >7000 fps (244 to >2134 mps) up to depths of 150 feet (46 m) below the ground surface indicating good excavatability. The soils are suitable for excavation of: vertical shelters by augers, continuous trenches (cast-in-place trench construction) by an MX trencher, and horizontal shelters, by conventional equipment.

In approximately 40 to 50 percent of the Sterling and Scott City sites the walls of a vertical shelter excavation may be unstable, requiring slurry or other techniques to support them. In approximately five percent of the Cimarron site, well-indurated discontinuous caliche interbeds may be encountered which have to be excavated by blasting.

Depth to rock is greater than 150 feet (46 m) over approximately 85 to 90 percent of the Sterling and Cimarron sites, thus minimizing additional expense for excavation of vertical shelters. However, in approximately 40 percent of the Scott City site depth to excavatable rock (Pierre Shale) is less than 150 feet, thus increasing excavation costs.

Depth to ground water is less than 150 feet (46 m) over approximately 55 to 60 percent of the Sterling and Scott City sites, thus increasing cost of excavation for vertical shelters. However, in only 15 percent of the Cimarron site depth to ground water is less than 150 feet.

- o Backfill - Suitability of the soils for backfill and compaction in trench excavations generally ranges from poor to fair. Due to the fine-grained nature of soils, mixing additional water with the soils will be an expensive operation. In addition, more compactive effort than for coarse-grained soils will be required to achieve the same degree of relative compaction.
- o Aggregates and Water - Aggregates required for concrete and roads will have to be imported from outside thus increasing haul costs. Sufficient quantities of water required for concrete and roads are available within and/or adjacent to the sites.

7.0 CONCLUSIONS

In summary, the Sterling, Scott City and Cimarron sites present favorable geotechnical conditions for the in-line hybrid trench basing mode because of the ease of excavation and adequate stability of the soils allowing economical cast-in-place construction. For the vertical and horizontal shelter basing modes, the sites present unfavorable geotechnical conditions because of poor road support characteristics of surficial soils. In addition, cost of excavation for vertical shelters will be high due to presence of ground water within the construction zone. As an alternative, areas with ground water within the construction zone can be excluded for the vertical shelter basing mode. Geotechnical conditions from the three sites can be extrapolated to approximately 67 percent of the Central High Plains CSP.

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MX SITING INVESTIGATION. PRIME CHARACTERIZATION SITES CENTRAL H--ETC(U)

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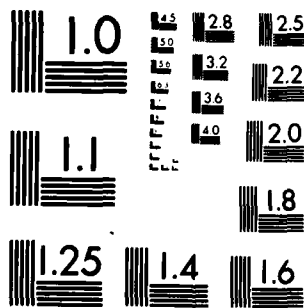
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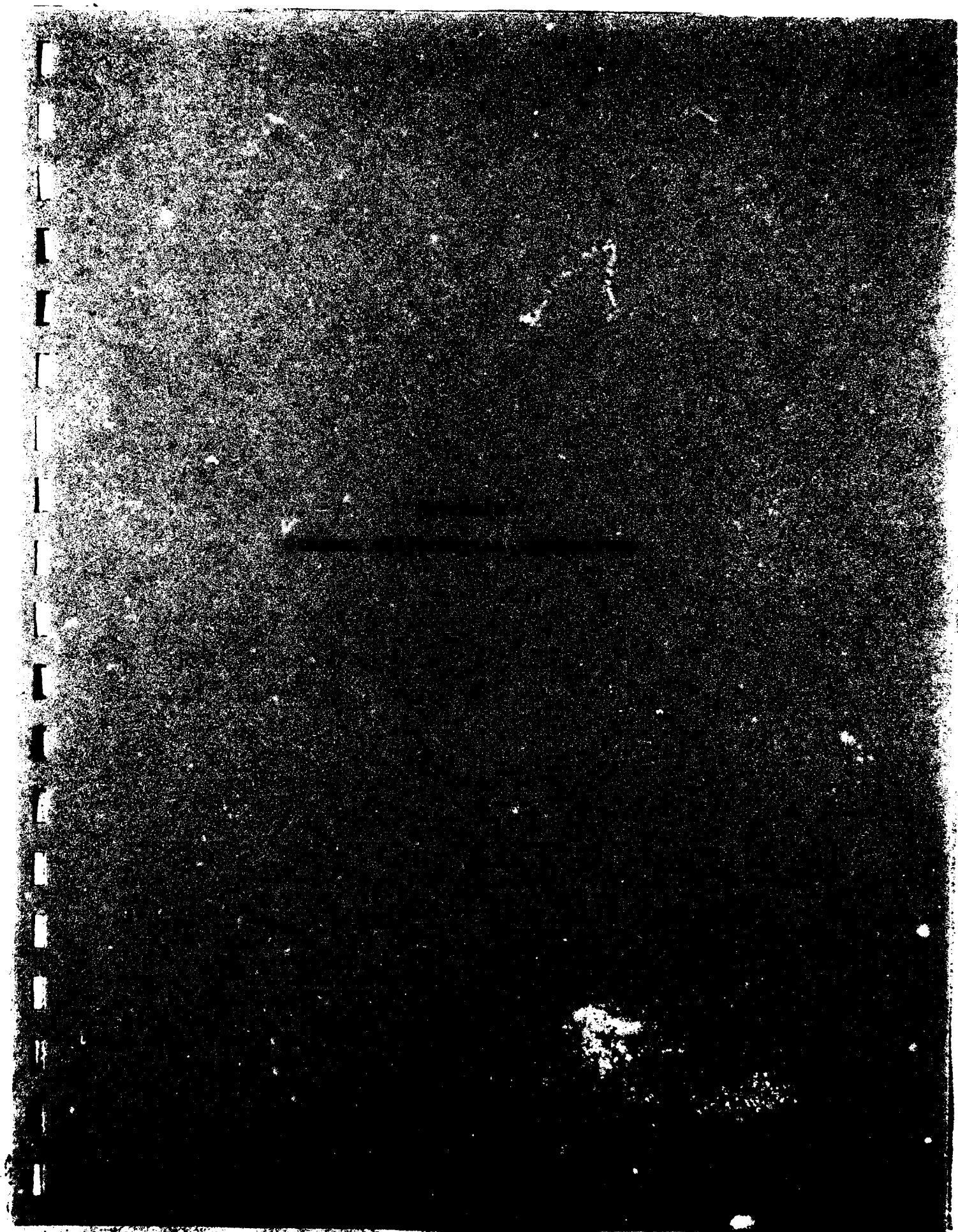


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UNIFIED SOIL CLASSIFICATION SYSTEM	A-2

GLOSSARY OF TERMS

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

AEROMAGNETIC DATA - Magnetometer observations made from an airplane.

ALLUVIAL BASIN - A lowland area, generally between uplifted mountain blocks, filled with alluvial deposits.

ALLUVIAL FAN - A low, outspread, relatively flat to gently sloping mass of alluvium, shaped like an open fan or a segment of a cone, deposited by a stream (especially in a semiarid region) at the place where it issues from a narrow mountain valley upon a plain or broad valley. It is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with gradually decreasing gradient.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIAL PLAIN - A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ANOMALY - 1) A deviation from uniformity in physical properties; especially a deviation from uniformity in physical properties of exploration interest. 2) A portion of a geophysical survey which is different in appearance from the survey in general.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

GLOSSARY OF TERMS (Cont.)

ARKOSIC SANDSTONE - A sandstone with considerable feldspar, such as one containing minerals from coarse-grained quartzo-feldspathic rocks (granites, granodiorites, medium or high-grade schists) or from older, highly feldspathic sedimentary rocks; specifically a sandstone containing more than 25% feldspar and less than 20% matrix material of clay, sericite, and chlorite.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a line-up of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BEDROCK - Rock with a seismic p-wave velocity of 7000 ft (2333 m) per second or more.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation and terrain corrections have been applied to gravity data.

BOULDER FIELD - Five or more rocks, each with diameters of 6 ft or more occurring within an acre.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to inter-particle friction).

CALICHE - Gravel, sand or other material cemented principally by calcium carbonate.

GLOSSARY OF TERMS (Cont.)

CALIFORNIA BEARING RATIO (CBR) - A test performed on a specifically prepared soil sample which is useful in the design of road pavement to be supported by the soil tested (ASTM D1833-73). The load is applied on the penetration piston which is penetrated into the soil sample at a constant penetration rate. The bearing ratio reported for the soil is normally the one at 0.1 inches (2.5 mm) penetration.

CANDIDATE - One of some group of regions, areas or sites being considered for MX deployment. Removal of candidate from a specifically named region, area or site term indicates selection by SAMSO/MNND.

CANDIDATE DEPLOYMENT AREA (CDA) - An area encompassing between 500 and 1000 square nautical miles of potentially suitable land with either naturally or artificially defined boundaries designated for convenience of study, discussion and data depiction. The candidate deployment area could be composed of two to four parcels and should have a specific place name description.

CANDIDATE DEPLOYMENT PARCEL (CDP) - An area of 150 to 500 square nautical miles potentially suitable for MX siting which, when aggregated with others, forms a Candidate Deployment Area. Each parcel should have a specific geographic description. (In the Basin and Range Physiographic province a parcel may correspond to a geographic valley and in Texas to some agri-economic unit.)

CANDIDATE DEPLOYMENT SITE (CDS) - A non-specific (i.e. not finally approved) site proposed for some element of the MX system within a chosen deployment area (i.e. trench or shelter site).

CANDIDATE SITING PROVINCE (CSP) - An area potentially suitable for deployment of the MX system generally encompassing more than 6000 square nautical miles which, in a broad sense, is homogeneous with respect to most of the important characteristics governing siting of a total MX system.

CANDIDATE SITING REGION (CSR) - Potentially suitable area between 4000 and 6000 square nautical miles within one, or encompassing portions of more than one, candidate siting province which allows for full MX deployment.

GLOSSARY OF TERMS (Cont.)

- CAPABLE (fault) - Movement at or near the surface at least once in the past 35,000 years, and/or more than once in the past 500,000 years, (Nuclear Regulatory Commission).
- CAPROCK - A resistant, moderately to strongly cemented caliche layer forming a "cap" over less resistant layers.
- CD TRIAXIAL SHEAR-A type of test to measure the shear strength of an undisturbed soil sample
- CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation.
- COARSE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.075 mm in diameter (passing the No. 200 U.S. size).
- COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material larger than 3 inches (76 mm) in diameter.
- COLLUVIAL DEPOSITS - A general term applied to any loose, heterogenous, and incoherent mass of soil material or rock fragments deposited chiefly by dislodgement and downslope transport of the material under the direct application of gravitational body stresses. Material is usually found at the base of a steep slope or cliff.
- COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D1557-70).
- COMPRESSIBILITY-Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.
- COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.
- CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

GLOSSARY OF TERMS (Cont.)

CONTERMINOUS UNITED STATES - The contiguous 48 states.

CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.

DEBRIS FLOW - A high-density flow of mud containing abundant coarse-grained materials (boulders, cobbles, gravel, sand) that frequently result from an unusually heavy rain.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DETECTOR - See GEOPHONE.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.

DISTAL - That portion of an alluvial deposit farthest from its point of origin.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current

ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current

ENTRENCH - The process whereby a stream erodes downward to form a trench.

EOLIAN - A term applied to materials which are deposited by wind.

EPHEMERAL(stream) - A stream in which water flow is discontinuous and of short duration.

EXTERNAL DRAINAGE - Stream drainage system whose downgradient flow is unrestricted by any topographic impediments.

EXTRUSIVE (rock) - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite; detrital material, volcanic tuff, pumice).

GLOSSARY OF TERMS (Cont.)

FAULT - A plane or zone of rock fracture along which there has been displacement.

FAULT BLOCK MOUNTAINS - Mountains that are formed by normal faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.075 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).

FLOODING/LOW ENERGY FLOW - Flood waters flowing on a slope of low gradient.

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness

FREE AIR ANOMALY - Gravity data which have been corrected for latitude and elevation (free air correction) but not for the density of rock between the datum and the plane of measurement (Bouguer correction).

FUGRO DRIVE SAMPLE - A 2.50 inch (6.4 cm) diameter soil sample obtained from a drill hole with a Fugro Drive Sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch (2.54 cm) long brass sample rings. The sampler is advanced into the soil using a drop-hammer.

GAMMA - A unit of magnetic-field intensity. A gamma is 10^{-5} oersteds; sometimes expressed (incorrectly) as 10^{-5} gauss with which it is numerically equal.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

GEOPHONE - The instrument used to transform seismic energy into electrical voltage; a seismometer, jug, or pick-up.

GLOSSARY OF TERMS (Cont.)

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.075mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of the particle sizes smaller than 0.075 mm is determined by a sedimentation process, using a hydrometer.

GRAVEL - Particles of rock that pass a 3-in. (76.2 mm) sieve and retained on a No. 4(4.75 mm) sieve

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GRAVITY GRADIENT - The partial derivative of the acceleration of gravity with respect to distance in a particular direction, for which purpose the acceleration of gravity is considered as a scalar.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in pre-existing rock. (e.g. granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in lake environment.

LINE - A linear array of observation points, such as a seismic line.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOESS - A wind blown deposit predominantly silt or silty clay or clayey silt.

LOW ENERGY FLOW - See FLOODING.

MAGNETIC INTENSITY - A vector quantity measuring magnetic field strength. The unit of magnetic intensity commonly used in geophysical exploration is the gamma (see GAMMA).

MANTLED PLAYA - A playa surface or a portion of the surface that is covered with younger geologic material such as windblown sand, or alluvium.

MILLIGAL - A unit of acceleration used with gravity measurements; 1 milligal = 10^{-5} m/sec.². Abbreviated mgal.

GLOSSARY OF TERMS (Cont.)

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dry weight of the sample.

N VALUE - Penetration resistance, number of blows required to drive the standard split spoon sampler for the second and third six inches (0.15 m) with a 140 pound (63.5 kg) hammer falling 30 inches (0.76 m) (ASTM D1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort

OVERBANK FLOODING - A large flow of water that overflows the sides of A stream channel.

O - Angle of internal friction

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering after long exposure (e.g., desert varnish).

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case the armored surface is formed by dissolution and cementation of the grains involved.

PEGMATITE DIKE - A coarse grained igneous rock of granitic composition that forms as a tabular intrusion that cuts across the planar structures of the surrounding rock.

P-WAVE - See COMPRESSIONAL WAVE.

PERIMETER SEISMIC REFRACTION SURVEY - Shallow seismic refraction measurements made around the perimeter of a valley.

PERMEABLE - The ability of liquid to pass through soil and/or rock material.

PICK-UP - See GEOPHONE.

GLOSSARY OF TERMS (Cont.)

- PITCHER TUBE SAMPLE - An undisturbed, 2.87 inch (73 mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.
- PLASTIC LIMIT - See ATTERBERG LIMITS.
- PLASTICITY INDEX - See ATTERBERG LIMITS.
- PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of fine clay, silt, or sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.
- PONDING (of water) - The accumulating of water in a topographic depression.
- PRIME - Modifier used to indicate the highest ranking province, region, area, or site. If not an interdisciplinary ranking, then a qualifier should be used such as "prime geotechnical candidate siting area".
- PROXIMAL - That portion of an alluvial deposit nearest to its point of origin.
- REGIONAL - The general attitude or configuration disregarding features smaller than a given size. The regional gravity is the gravity field produced by large-scale variations ignoring anomalies of smaller size. See residualize.
- RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.
- RESIDUAL - What is left after a regional field has been removed, as in gravity or magnetic analysis. See RESIDUALIZE.

GLOSSARY OF TERMS (Cont.)

RESIDUALIZE - The process of separating a graphically depicted curve or a surface into its low-frequency parts (called the regional) and its high-frequency parts (called the residual). Residualizing is an attempt to sort out of the total field those anomalies which result from local structure; that is, to fine local anomalies by subtracting gross (regional) effects.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

S-WAVE - See SHEAR WAVE.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC REFRACTION DATA: deep/shallow - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have travelled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See GEOPHONE.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-Wave or transverse wave.

SHEET FLOW - A process in which storm-borne water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

GLOSSARY OF TERMS (Cont.)

- SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.
- SILT AND CLAY - Fine-grained soil passing through No. 200 (0.075 mm) sieve.
- SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.
- SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.
- SPLIT SPOON SAMPLE - A disturbed sample obtained with a split spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop-hammer.
- SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing twenty-four geophones have been used in Fugro's seismic refraction surveys.
- STREAM CHANNEL DEPOSITS - Materials (clay, silt, sand, gravel, cobbles, boulders) which have been deposited in a stream channel.
- STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.
- SURFICIAL DEPOSIT - Unconsolidated residual and alluvial deposits occurring on or near the earth's surface.
- TRANSITORY - A poorly defined, shallow ephemeral stream across an alluvial fan surface, the position of which is temporary and tends to shift frequently.
- UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed soil sample.
- UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification on the basis of grain-size distribution and Atterberg Limits. (See page A-17).

GLOSSARY OF TERMS (Cont.)

VALLEY SEISMIC REFRACTION SURVEY - Deep seismic refraction measurements made near the middle of a valley to determine seismic wave propagation velocities and thickness of basin fill.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogenous seismic velocity.

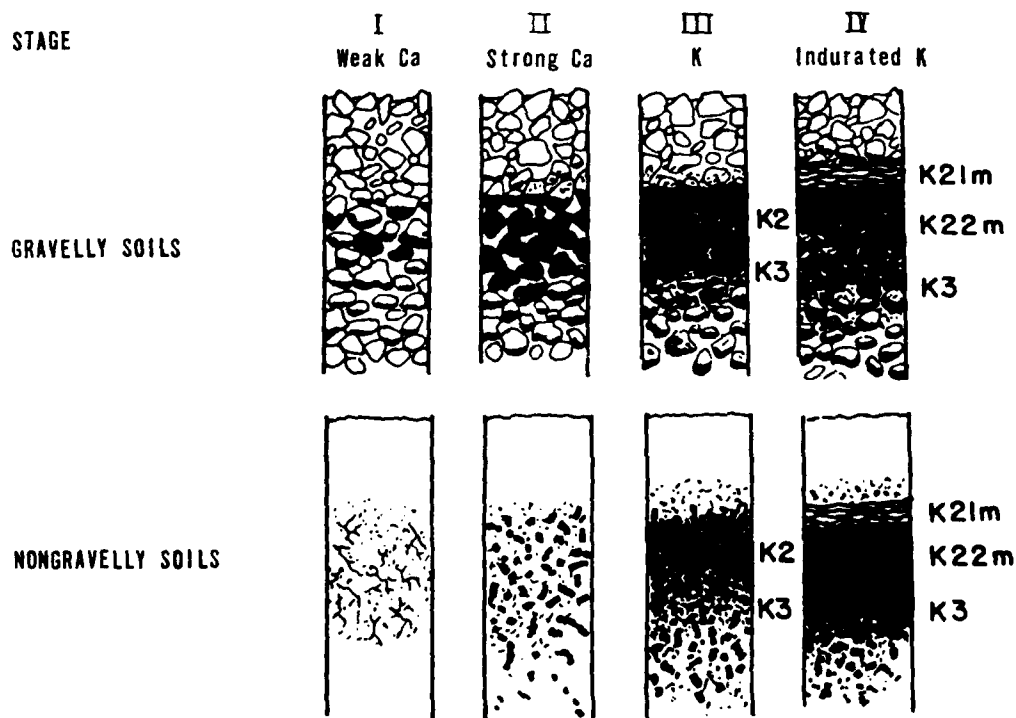
VELOCITY PROFILE - A cross-section showing the distribution of material seismic velocities as a function of depth and its configuration.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling to obtain lithologic information between samples.

Definitions were derived in part from Webster's New Collegiate Dictionary (1972 edition), Glossary of Geology (American Geological Institute, 1972), Encyclopedic Dictionary of Exploration Geophysics (Sheriff, 1973), and 1976 Annual Book of ASTM Standards.

DIAGNOSTIC CARBONATE MORPHOLOGY

STAGE	GRAVELLY SOILS	NONGRAVELLY SOILS
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Laminar horizon overlying plugged horizon



Stages of development of a caliche profile with time. Stage I represents incipient carbonate accumulation, followed by continuous build-up of carbonate until, in Stage IV, the soil is completely plugged.

SUMMARY OF CALICHE DEVELOPMENT

Reference: Gile, L.H., Peterson, F.F., and Grossman, R.B., 1965.
The K horizon: A master horizon of carbonate accumulation; Soil Science, v. 89, p. 74-82.

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS

FIGURE
A-1

FUGRO NATIONAL, INC.

(1) AREI
SYMBOLS

MX (2)
GEOLOGIC
UNITS

NON-ROCK UNITS

(1) AREI
SYMBOLS

MX
GEOLOGIC
UNITS

Au, Ast	Au	Non-rock Deposits (undifferentiated); fine- to coarse-grained materials deposited by alluvial, fluvial, eolian, lacustrine, gravity or glacial processes.		
Aal	A1	Fluvial Deposits; predominantly composed of poorly- to well-graded sand and gravel with lesser amounts of silt- and boulder-sized material. The unit predominantly consists of recent water-laid deposits occupying present drainages and flood plains. - Older Fluvial Deposits (A1o) are generally thicker, more extensive units deposited in ancestral fluvial systems. - Alluvial Outwash Deposits (A1w) consist of mixed, geomorphically nondescript alluvial and fluvial deposits covering large, relatively flat, river and playa basins.	gr Vu Vb	I
At	A2	Terrace Deposits; predominantly composed of moderately to well graded, clay- to gravel-sized material. Principally elevated terraces bordering modern streams (A2s) and lakes/playas (A2l).	Su	S
	A3	Eolian Deposits; predominantly composed of poorly graded sand-sized material deposited by wind action. Deposits may consist of mixed sand, silt, and clay (A3u), or be differentiated on the basis of predominant grain size and landform. A3s d - Predominantly fine sand-sized material deposited in sheets (A3s) or dunes (A3d). A3l - Loess composed predominantly of silt-sized material with lesser amounts of clay and fine sand. A3f - Predominantly clay-sized material with lesser amounts of silt and fine sand.	Qtz Psa, Pm, Ph, Cau, Ls, Py, Par	
	A4	Lacustrine, Estuarine, and Playa Deposits; predominantly composed of poorly graded clay, silt, and fine sand deposited in bodies of standing water. Older lacustrine, estuarine, and playa deposits (A4o) are thicker, more extensive units occupying ancestral lake basins.	Qtz, gn	M
Aaf	A5	Alluvial Fan Deposits; predominantly composed of well graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited principally by distributary channels adjacent to mountain fronts. Relative ages are indicated by o - older, i - intermediate, or y - younger.		C
	A6	Pediment, Pediment Deposits, and Areas of Shallow Rock; planated bedrock shelf or near surface rock generally overlain by a thin mantle of sand- to boulder-sized residual or alluvial material.		
	A7	Colluvial Deposits; predominantly composed of moderately- to well-graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited locally by gravity and water adjacent to steep gradients.		

NOTES (1) AREI symbols were developed for use in the Aggregate Resources Evaluation Investigation (See Section 5.1 and Drawings 5.1A through 5.1C)

(2) MX Geologic units were used for Methodology, Screening, and Characterization studies.

ROCK UNITS

Shown in regions where rock is exposed; the areally predominant (greater than 70 percent) rock type is indicated. In those areas where two rock types occur the predominant rock type is shown followed by the subordinate rock type (e.g. S2MP I4T).

I IGNEOUS (UNDIFFERENTIATED). Rocks formed by solidification of a molten or partially molten mass.

- gr I1 Intrusive - Typically crystalline, formed by the solidification of molten material below the surface (e.g., granite, syenite, diorite).
- Yu I2 Extrusive (undifferentiated). Formed by solidification of molten material at or near the surface.
- Yb I3 Extrusive (flows). Extrusive rocks formed by solidification of lava (e.g. basalt, dacite). Yb denotes young basaltic flows which may be interbedded with basaltic materials.
- I4 Extrusive (volcaniclastics). Formed by accumulation, welding and or cementation of deposits of volcanic ejecta (e.g. tuff, agglomerate, lapilli).

Su S SEDIMENTARY (UNDIFFERENTIATED). Coarse- to fine-grained materials that exhibit some degree of cementation and were deposited by water, wind, gravity, or evaporation.

- Qtz S1 Sandstone. Composed predominantly of sand-sized particles
- Psa, Pm, S2 Limestone and Dolomite. Composed predominantly of carbonate material.
- Ph, Cau, S3 Shale. Composed predominantly of clay- and silt-sized particles
- Ls, Py, (e.g. shale, siltstone, mudstone)
- Par S4 Evaporites. Sediments deposited from solution as a result of evaporation (e.g. gypsum, anhydrite, halite).
- S5 Clastics. Undifferentiated deposits composed of silt- to boulder-sized material. May be angular to rounded.

Qtz, gr M METAMORPHIC (UNDIFFERENTIATED). Rocks formed through alteration of igneous or sedimentary rock material by pressure, heat, or chemical changes below the weathered zone (e.g. gneiss, schist, slate, marble, quartzite).

C ROCK COMPLEXES. Indicated where no areally predominant (greater than 70 percent) rock type is present.

USAGE

Modifying letter (r) indicates concentrations of resistant secondary carbonate (caliche), silicious, ferruginous and or gypsiferous material, e.g. A5ir.

A3s A5y - Mixed non-rock units; most areally extensive unit is listed first.

A5y(A5i) - Parenthetic unit underlies thin veneer of overlying mapped unit.

S5to - Established formations may have a supplemental letter added to distinguish formal designation (e.g. Tertiary Ogallala Fm.).

EXPLANATION OF GEOLOGIC UNITS

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS

TABLE
 A-1

FUGRO NATIONAL INC.

2

Major Divisions		Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 inches and having fractions on estimated weights)	Information Required for Describing Soils
1	Coarse-grained Soils More than half of material is larger than No. 200 sieve size.	3	4	5	6
	More than half of material is smaller than No. 200 sieve size.				
2	Gravels More than half of coarse fraction is larger than No. 4 sieve size.	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compaction, cementation, moisture conditions and drainage characteristics.
	Gravels with fines (Appreciable amount of fines)				
3	Sands More than half of coarse fraction is smaller than No. 4 sieve size.	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	Give typical name; indicate approximate percentage of sand and gravel, the fineness, surface condition, and hardness of the coarse grains; soil or geologic name and other pertinent descriptive information; and symbol in parentheses.
	Sands with fines (Appreciable amount of fines)				
4	Silt and Clay Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses.
	Silt and Clay Liquid limit greater than 50				
5	Silt and Clay Liquid limit less than 50	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.
	Silt and Clay Liquid limit greater than 50				
6	Silt and Clay Liquid limit less than 50	OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
	Silt and Clay Liquid limit greater than 50				
7	Silt and Clay Liquid limit less than 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	
	Silt and Clay Liquid limit greater than 50				
8	Silt and Clay Liquid limit less than 50	CH	Inorganic clays of high plasticity, fat clays.	High to very high	
	Silt and Clay Liquid limit greater than 50				
9	Silt and Clay Liquid limit less than 50	OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	
	Silt and Clay Liquid limit greater than 50				
10	Silt and Clay Liquid limit less than 50	Pt	Peat and other highly organic soils.	None to very slow	
	Silt and Clay Liquid limit greater than 50				

UNIFIED SOIL CLASSIFICATION SYSTEM

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
A-2

FUGRO NATIONAL, INC.

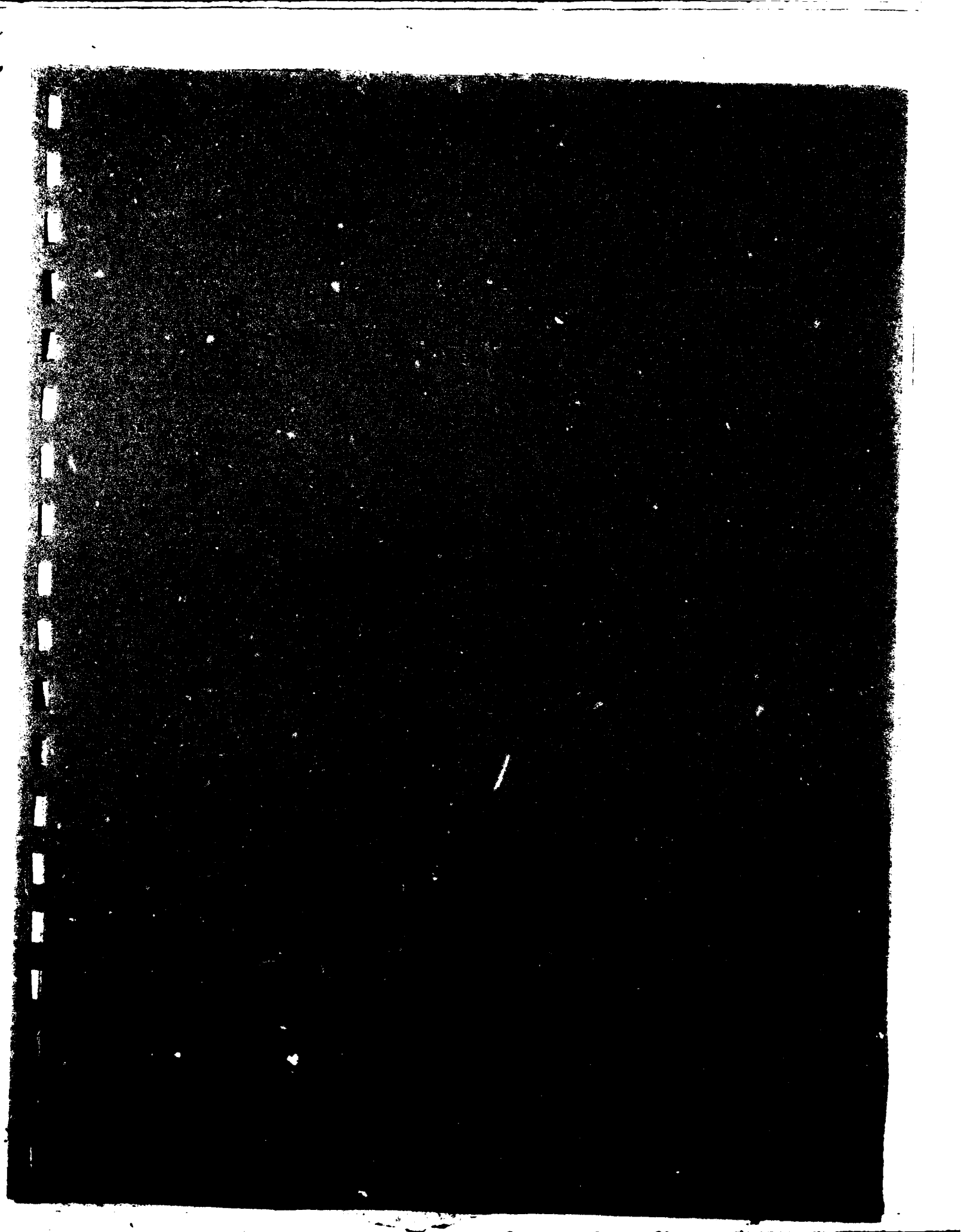


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SUMMARY OF LABORATORY TEST RESULTS

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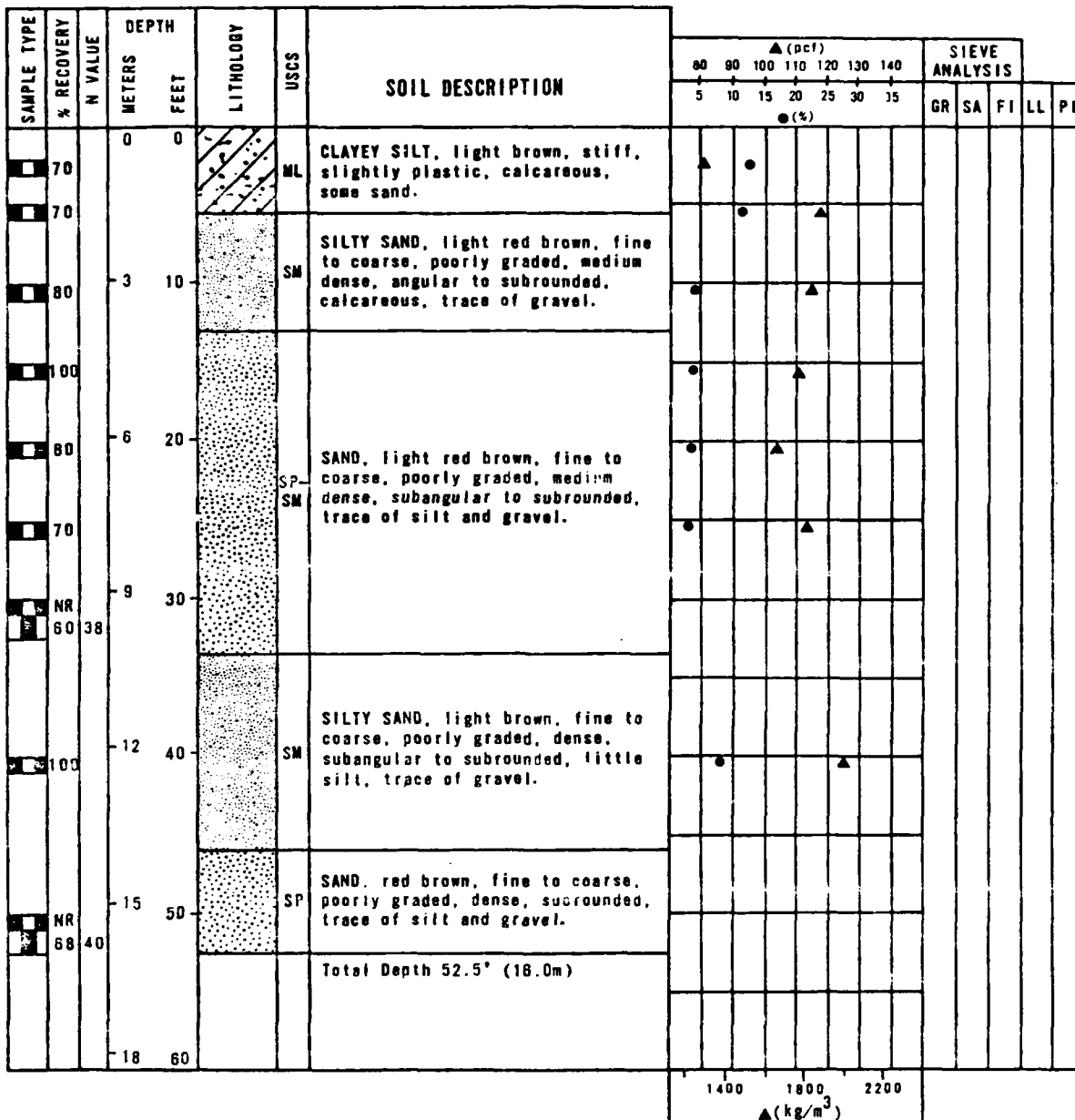
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SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

- N — STANDARD PENETRATION TEST (ASTM: D-1586-67)
- R — N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
- — MOISTURE CONTENT (ASTM: D-2216-71)
- NR — NO RECOVERY

BORING DETAILS

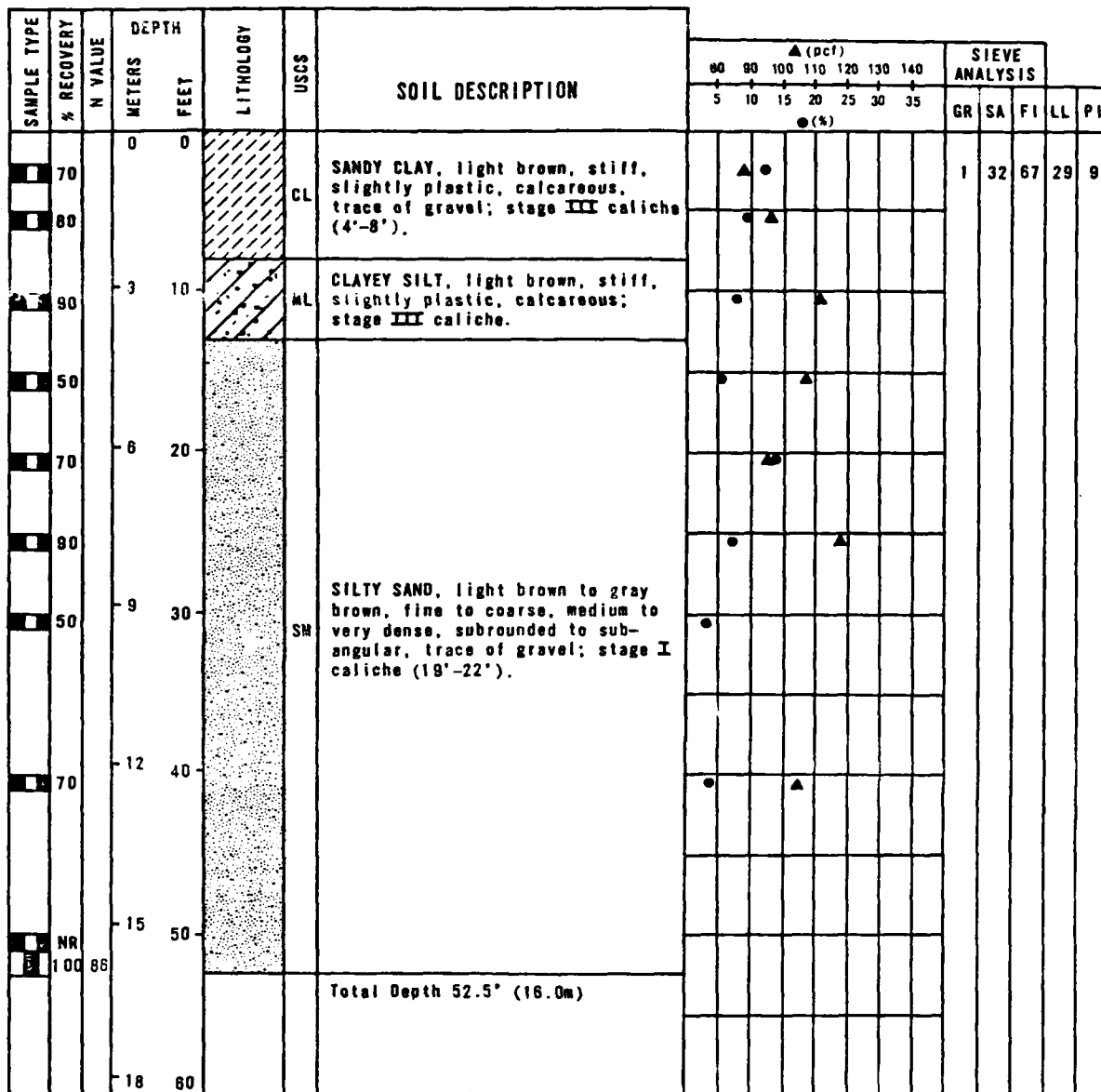
ELEVATION : 4130' (1259m)
 DATE DRILLED : 30 September 1977
 DRILLING METHOD : Hollow Stem Auger
 HOLE DIAMETER : 8 5/8" (188mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BORING SG-B-3 STERLING, COLORADO CENTRAL HIGH PLAINS CSP





MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
B-1

FUGRO NATIONAL, INC.



SAMPLE TYPES

-  STANDARD PENETRATION TEST
-  FUGRO DRIVE
-  BULK
-  PITCHER TUBE

ENGINEERING PARAMETERS

- N — STANDARD PENETRATION TEST (ASTM: D-1586-87)
- R — N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
- — MOISTURE CONTENT (ASTM: D-2216-71)
- NR — NO RECOVERY

BORING DETAILS

ELEVATION : 3964' (1208m)
 DATE DRILLED : 28 September 1977
 DRILLING METHOD : Hollow Stem Auger
 HOLE DIAMETER : 6 5/8" (168mm)
 CASING INSTALLED: None
 WATER LEVEL : Not Encountered

LOG OF BORING SG-B-5
 STERLING, COLORADO
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SANSO

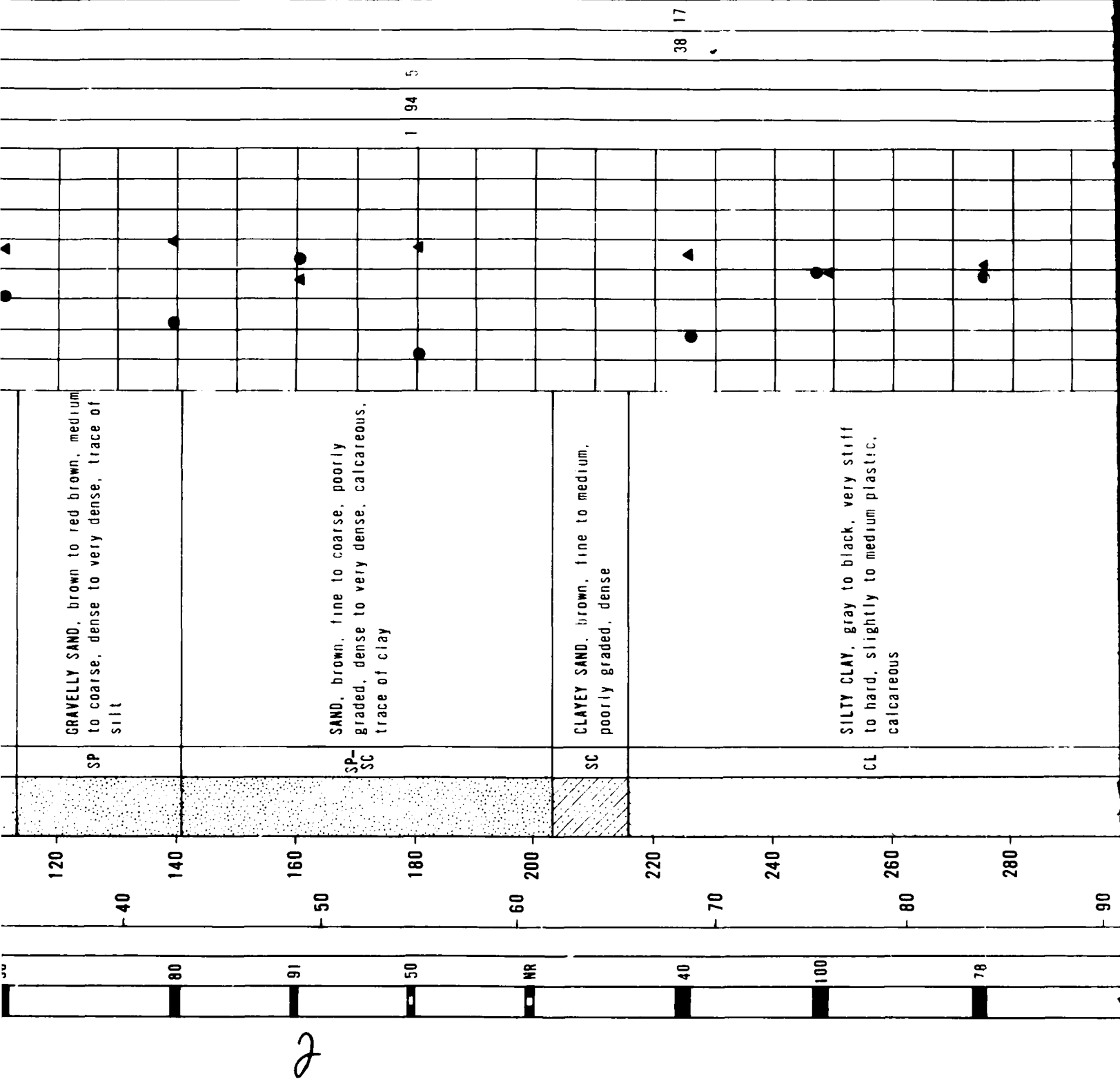
FIGURE
 B-2

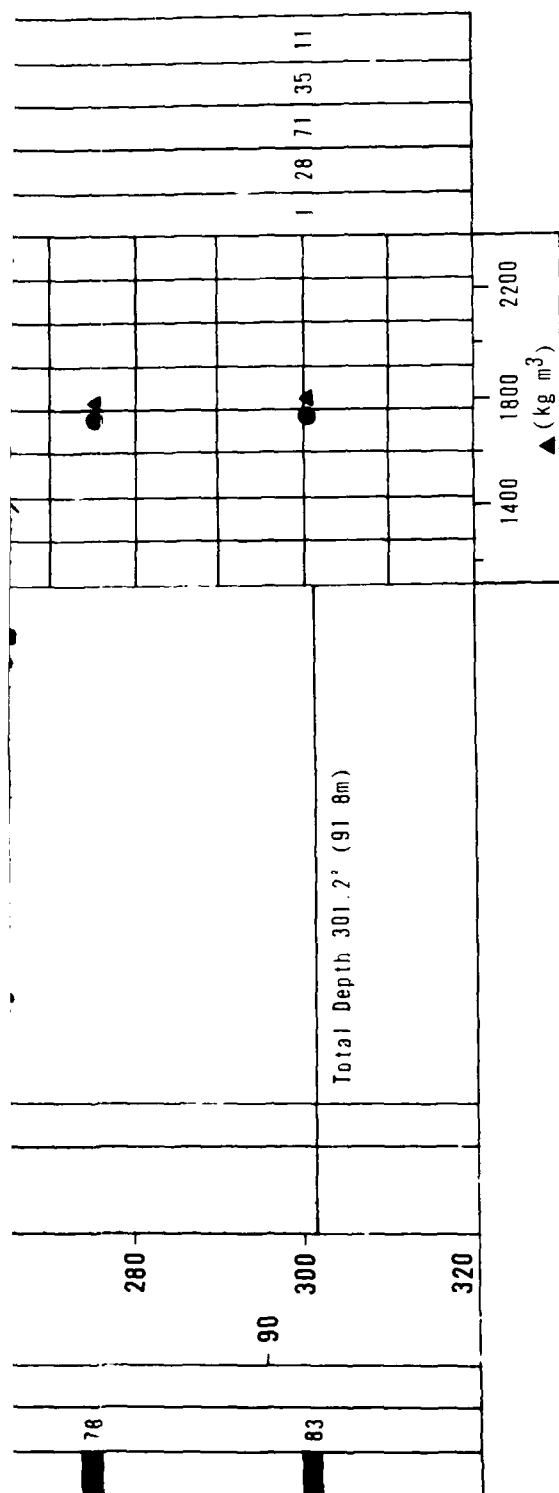
FUGRO NATIONAL, INC.

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)										SIEVE ANALYSIS		
								80	90	100	110	120	130	140	GR	SA	FI	LL	PI	
92	NR	52	0	0		SM	SILTY SAND, brown, fine to medium, poorly graded, loose (2-5') and dense to very dense, calcareous, trace of clay.	●	▲							1	64	35		
87	65	24	20	20						●	▲					1	72	27		
88	72	44																		
72	53									●		▲								
67	67																			
67	33															11	86	3		
88			10	40		SW	SAND, brown, fine to coarse, well graded, dense to very dense, calcareous, trace of fine gravel	●												
						CL	SANDY CLAY, light brown, stiff, slightly plastic, calcareous, trace of fine gravel	●												
73						SP-SM	GRAVELLY SAND, brown to red brown, medium to coarse, dense to very dense, trace of silt.	●				▲				16	79	5		
71			20	60				●				▲								
65																				
96				80		SM	SILTY SAND, brown, fine to medium, dense, trace of clay, trace of fine gravel			●		▲								
67										●										
			30	100		SP	GRAVELLY SAND, brown to red brown, medium to coarse, dense to very dense, trace of silt.	●				▲								
44										●										
96						SM	SILTY SAND, brown, fine to medium, dense, trace of clay, trace of fine gravel			●										
										●		▲								
			40	120		SP	GRAVELLY SAND, brown to red brown, medium to coarse, dense to very dense, trace of silt													

CHECKED BY

APPROVED BY





SAMPLE TYPES

□ STANDARD PENETRATION TEST

■ FUGRO DRIVE

□ BULK

■ PITCHER TUBE

▨ CORE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)

● - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 4120' (1256m)

DATE DRILLED : 28-30 September 1977

DRILLING METHOD : Rotary Wash

HOLE DIAMETER : 4 7/8" (124mm)

CASING INSTALLED : None


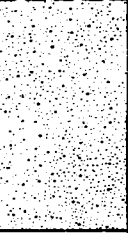
WATER LEVEL : Not Encountered

LOG OF BORING SG-B-6
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
B-3

FUGRO NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		CL	Stiff	SANDY CLAY, light to dark brown, medium plastic, slightly moist.					
	2										
	4										
	6										
	8										
	10										
	12										
	14										
	16										
	18										
	20			SM	Medium dense	SILTY SAND, gray brown, angular to subrounded, calcareous, slightly moist, trace of clay, trace of gravel; stage II caliche.					
	22										
	24										
	26										
	28					Total Depth 13.5' (4.1m) Stability of Vertical Walls: Stable 0-13.5' (4.1m)					
	30										
	32										
	34										
	36										
	38										
	40										
	42										
	44										
	46										
	48										
	50										
	52										
	54										
	56										
	58										
	60										
	62										
	64										
	66										
	68										
	70										
	72										
	74										
	76										
	78										
	80										
	82										
	84										
	86										
	88										
	90										
	92										
	94										
	96										
	98										
	100										

TRENCH DETAILS

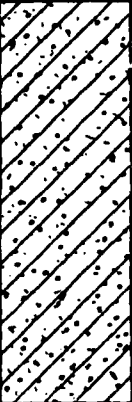
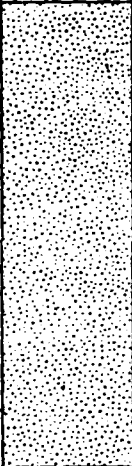
SURFACE ELEVATION : 4439' (1353m)
 DATE EXCAVATED : 27 September 1977
 SURFACE GEOLOGIC UNIT : A3L
 TRENCH LENGTH : 28' (8.5m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH SG-T-4
 STERLING, COLORADO
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
 B-4

FUGRO NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		ML	Firm	CLAYEY SILT, brown to light brown, slightly to medium plastic, weak calcareous cementation (1.9-6.9'), moist, trace of fine sand and fine gravel.					
		2									
		4									
		6									
		8									
		10									
	2			SP-SM	Medium dense	GRAVELLY SAND, red, fine to coarse, poorly graded, subrounded, moist, some fine gravel.					
		8									
		10									
		12									
		14									
		16									
	4					Total Depth 15.0' (4.6m) Stability of Vertical Walls: Stable 0-15.0' (4.6m)					
		18									
		20									
		22									
		24									
		26									

TRENCH DETAILS

SURFACE ELEVATION : 4130' (1259m)
 DATE EXCAVATED : 1 October 1977
 SURFACE GEOLOGIC UNIT : A3L
 TRENCH LENGTH : 28' (7.9m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH SG-T-13
 STERLING, COLORADO
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
 B-5

UGRO NATIONAL, INC.

BULK SAMPLE	DEPTH METERS FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
						GR	SA	FI	LL	PI
	0		CL	Stiff	SILTY CLAY, brown, slightly to medium plastic, slightly moist, trace of fine sand.					
	2								28	10
	4		CL	Stiff	SANDY CLAY, light gray to light red, slightly plastic, calcareous, slightly moist, trace of gravel (8-13').					
	6									
	8									
	10									
	12									
	14									
	16									
	18									
	20									
	22									
	14		SM	Medium dense	SILTY SAND, brown, fine to medium, poorly graded, calcareous, trace of clay and gravel.					
					Total Depth 14.4' (4.4m) Stability of Vertical Walls: Stable 0-14.4' (4.4m)					

TRENCH DETAILS

SURFACE ELEVATION : 4300' (1311m)
 DATE EXCAVATED : 2 October 1977
 SURFACE GEOLOGIC UNIT : A3L
 TRENCH LENGTH : 25' (7.6m)
 TRENCH ORIENTATION : NS

LOG OF TRENCH SG-T-17
 STERLING, COLORADO
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
 B-6

UGRO NATIONAL, INC.

JECK

(a) Sample types

P - Pitcher

0 - Fugro Drive

B - Bulk

(c) USCS - Unified Soil Classification System

* Indicates that test has been performed and results are included in this report.

NO. SIEVE NO					PARTICLE SIZE (mm)		ATTERBERG LIMITS (b)			USCS (c)	IN-SITU				COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL	UNCONFINED COMPRESSION	DIRECT SHEAR	CONSOLIDATION
			SILT OR CLAY		LL	PL	PI	DRY UNIT WEIGHT			MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)						
NO	100	200	.005	.001				(pcf)	(kg/m³)					(pcf)	(kg/m³)							
4	53	35							SM	97.7	1565	5.3	19.8	0.70				*				
									SM	107.1	1716	18.3	86.4	0.57								
6	38	27	11	8					SM	103.9	1664	19.5	84.9	0.62				*				
									SM	114.9	1841	10.4	60.2	0.47								
1	5	3							SW	118.5	1898	1.8	11.2	0.42								
									SW	106.9	1712	18.7	87.2	0.57								
	7	5							SP-SM	121.2	1940	8.2	57.0	0.39								
									SP-SM	113.0	1810	12.8	70.7	0.49								
									SM	112.8	1807	17.0	93.1	0.49								
									SM	113.5	1818	15.6	87.3	0.48								
									SP	119.1	1908	3.6	23.4	0.42								
									SM	107.5	1722	17.9	85.6	0.57								
									SM	116.4	1865	15.2	92.0	0.45								
									SP	119.8	1919	10.9	72.4	0.41								
									SP-SC	105.5	1690	21.8	98.6	0.60								
3	4	5							SP-SC	116.8	1871	5.8	35.3	0.44								
					38	21	17		CL	114.7	1837	9.1	52.4	0.47				*				
									CL	108.8	1743	19.5	96.4	0.55								
									CL	110.8	1775	19.3	100.3	0.52								
7	93	71	34	19	35	24	11		CL	112.0	1794	19.4	104.3	0.50								
</																						

2

SUMMARY OF LABORATORY
BORING
STERLING, COLORADO, CO
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE
FUGRO NAT

3

[illegible]

SUMMARY OF UNCONFINED COMPRESSION TEST RESULTS

STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - S&MSO

TABLE
B-2**FUGRO NATIONAL, INC.**

SUMMARY OF TRIAXIAL SHEAR TEST RESULTS STERLING, COLORADO CENTRAL HIGH PLAINS CSP	
WX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMS0	TABLE B-3
FUGRO NATIONAL, INC.	

<p>SUMMARY OF DIRECT SHEAR TEST RESULTS STERLING, COLORADO CENTRAL HIGH PLAINS CSP</p>	
<p>MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMSO</p>	<p>TABLE B-4</p>
<p>UGRO NATIONAL, INC.</p>	

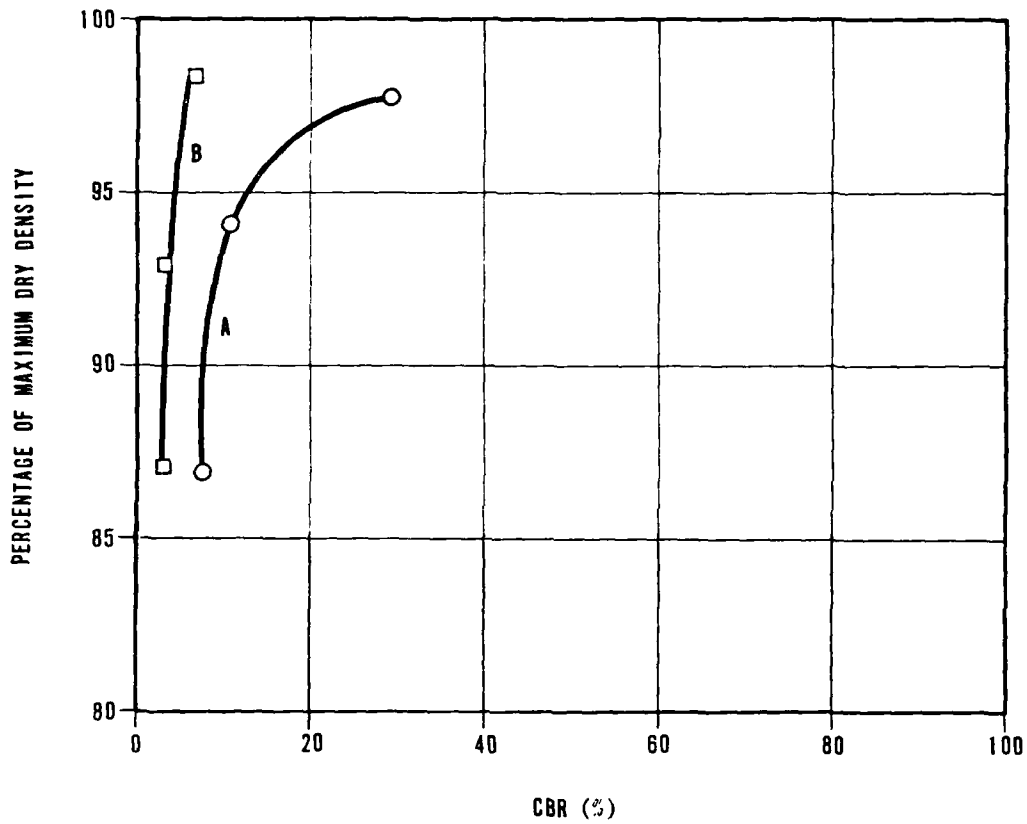
COMPOSITE SAMPLE NUMBER	SOIL TYPE	PERCENT PASSING #200	ATTERBERG LIMITS		SPECIFIC GRAVITY	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)	COMPACTED DRY DENSITY		COMPACTED MOISTURE (%)	PERCENT OF MAXIMUM DRY DENSITY	CBR (%)
			LL	PI		pcf	kg/m ³		pcf	kg/m ³			
A	CL	54	28	11	2.64	125.0	2002	10.5	122.1	1956	10.7	97.7	29
									118.3	1895	10.8	94.6	11
									108.8	1743	10.9	87.0	8
B	CL	82	36	16	2.61	115.2	1846	15.2	113.2	1813	15.3	98.3	7
									107.0	1714	15.2	92.9	5
									100.3	1607	15.2	87.1	5

CALIFORNIA BEARING RATIO
(CBR) TEST RESULTS
STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
B-5

FUBRO NATIONAL, INC.



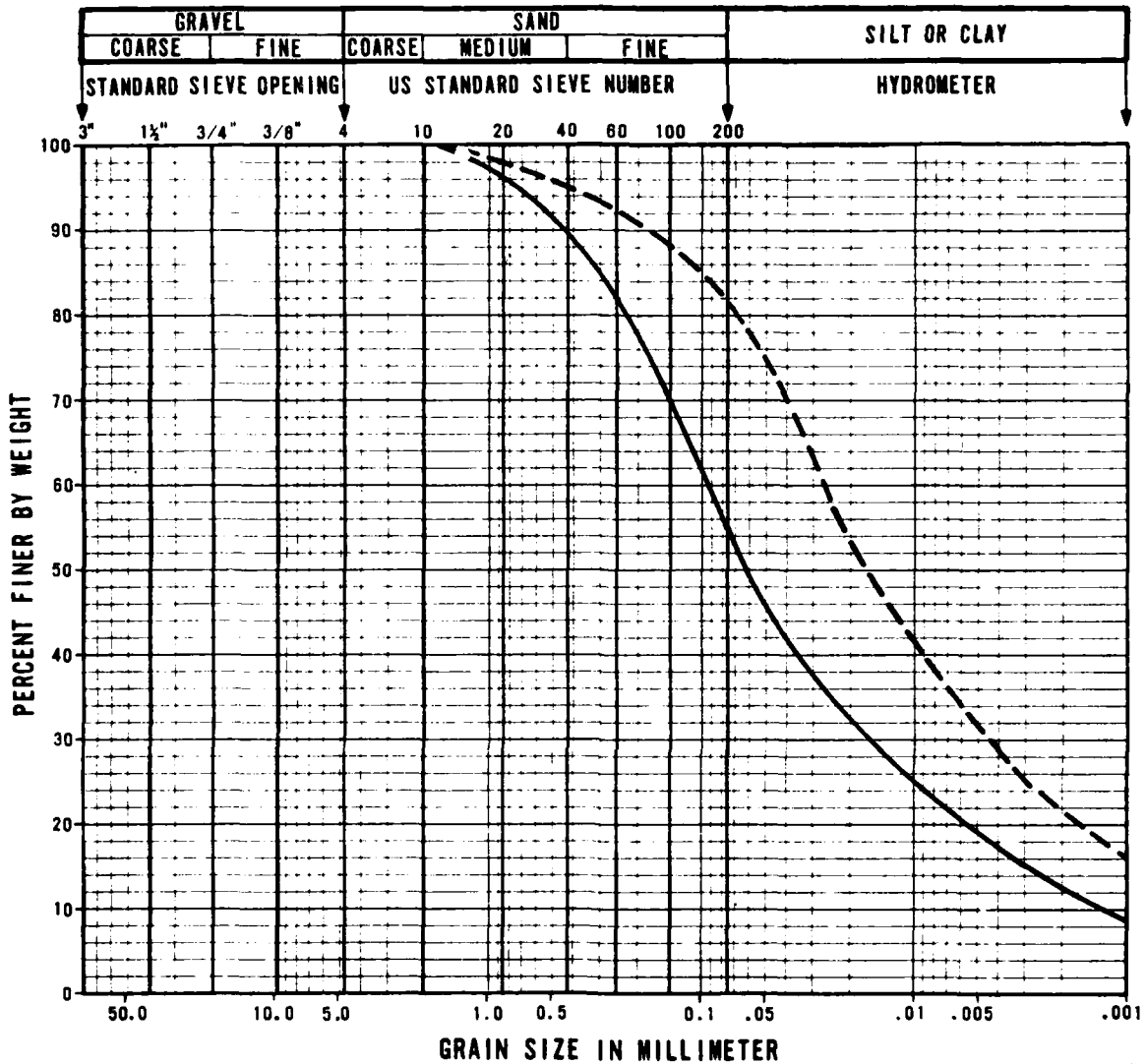
SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	CL
□	B	CL

CALIFORNIA BEARING RATIO
(CBR) CURVES
STERLING, COLORADO, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
B-7

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	SG-T-8	1.0 - 3.4	0.30 - 1.04	CL
		SG-T-9	0.5 - 1.4	0.15 - 0.43	
---	B	SG-T-12	1.0 - 2.5	0.30 - 0.76	CL
		SG-T-14	0.5 - 1.5	0.15 - 0.46	
		SG-T-15	1.0 - 2.0	0.30 - 0.61	

GRAIN SIZE CURVES, CBR TESTS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
B-8

FUGRO NATIONAL, INC.

[illegible]

SUMMARY OF CHEMICAL TEST RESULTS
STERLING, COLORADO
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

**TABLE
B-6**

FUGRO NATIONAL, INC.

APPENDIX C
GEOTECHNICAL DATA - SCOTT CITY

TABLE OF CONTENTS
APPENDIX C

BORING AND TRENCH LOGS

LOG OF BORING SY-B-2	Figure C-1
LOG OF BORING SY-B-6	Figure C-2
LOG OF BORING SY-B-11	Figure C-3
LOG OF TRENCH SY-T-7	Figure C-4
LOG OF TRENCH SY-T-8	Figure C-5
LOG OF TRENCH SG-T-13	Figure C-6

SUMMARY OF LABORATORY TEST RESULTS

BORING SY-B-6	Table C-1
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SUMMARY OF SHEAR STRENGTH TESTS

UNCONFINED COMPRESSION TEST RESULTS	Table C-2
TRIAXIAL SHEAR TEST RESULTS	Table C-3
DIRECT SHEAR TEST RESULTS	Table C-4

SUMMARY OF CALIFORNIA BEARING RATIO (CBR) TESTS

CALIFORNIA BEARING RATIO (CBR) TEST RESULTS	Table C-5
CALIFORNIA BEARING PATIO (CBR) CURVES	Figure C-7
GRAIN SIZE CURVES, CBR TESTS	Figure C-8

SUMMARY OF CHEMICAL TEST RESULTS

Table C-6

CHECKED BY _____ APPROVED BY _____

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)										SIEVE ANALYSIS			
							80	90	100	110	120	130	140	GR	SA	FI	LL	PI		
	92		0		CL	SILTY CLAY, brown, firm to stiff, slightly plastic, calcareous.	▲	▲												
	88		3			CLAYEY SILT, light brown, firm, slightly plastic, calcareous, trace of fine sand, layer of silty clay (35-38')	▲	▲												
	92		10				▲													
	100		20				▲							0	3	97	30	2		
	100		30				▲													
	92		38		CL		▲													
	88		42			SILTY SAND, red brown, fine, poorly graded, dense to very dense	▲	▲						0	71	29				
	90		50		SM		▲													
	92		18		SP & GP	SAND and GRAVELLY SAND, interbedded. SAND: brown, fine, poorly graded, very dense. GRAVELLY SAND: fine to coarse, very dense	▲													

UP
GRAVELLY SAND, fine to coarse, very dense

-21 70
-24 80
-27 90
-30 100
-33 110
-36 120
-39 130

25

71

59

73

CLAYEY SAND, brown and white, fine to medium, poorly graded, dense to very dense, calcareous.

SAND, brown, medium to coarse, poorly graded, very dense, trace of fine gravel, layer of gravelly sand (95-98') with fine to coarse gravel.

CLAYEY SAND, red brown and white, fine to medium, very dense, calcareous, trace of fine gravel.

Total Depth 102.2' (31.2m)

1400 1800 2200
▲ (kg. m³)

SAMPLE TYPES

☒ STANDARD PENETRATION TEST

☒ FUGRO DRIVE

☐ BULK

☐ PITCHER TUBE

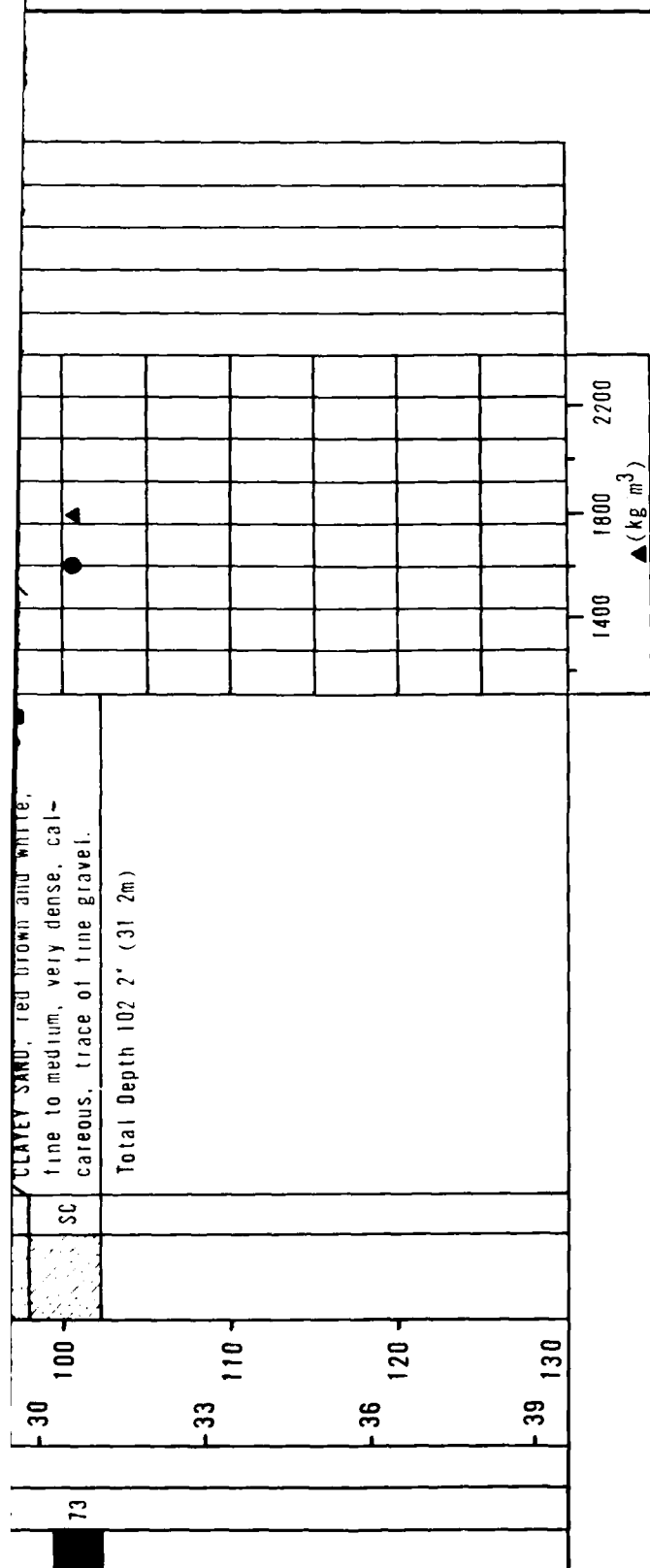
BORING DETAILS

ELEVATION : 3430' (1045m)
DATE DRILLED : 4-5 October 1977
DRILLING METHOD : Rotary Wash
HOLE DIAMETER : 4 7/8" (124mm)
CASING INSTALLED : None
WATER LEVEL : Not Apparent

LOG OF BO
SCOTT CI
CENTRAL HI

MX SITING INVEST
DEPARTMENT OF THE AIR

FUGRO NAT



SAMPLE TYPES

☐ STANDARD PENETRATION TEST

☐ FUGRO DRIVE

☐ BULK

☐ PITCHER TUBE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

Δ - DRY UNIT WEIGHT (ASTM: D-2937-71)

\bullet - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 3430' (1045m)
 DATE DRILLED : 4-5 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Apparent

LOG OF BORING SY-B-2
 SCOTT CITY, KANSAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMSQ

FIGURE
 C-1

FUGRO NATIONAL, INC.

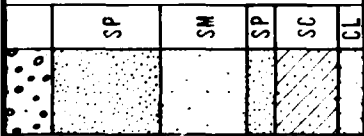
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SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)											SIEVE ANALYSIS			
								80	90	100	110	120	130	140	GR	SA	FI	LL	PI			
	96		0	0	CL	CL	SILTY CLAY, dark brown, firm, slightly to medium plastic, calcareous.	▲	▲									0	2	98	29	6
	92				ML	ML	CLAYEY SILT, light brown, firm, slightly to medium plastic, calcareous.	▲	▲													
	84			20				▲	▲													
	88																					
	64																					
	52																					
	96		-10			CL	SILTY CLAY, light brown, and white, firm, slightly to medium plastic, calcareous	▲	▲									0	3	97	40	19
	64		40																			
	NR	68				SP & GP																
	80			60																		
	67	R																				
	20		-20			CL																
	53	64																				
	100	98		80		SP & GP	SAND and GRAVELLY SAND, SILTY SAND. CLAYEY SAND, SANDY GRAVEL and SANDY CLAY; interbedded.															
	87	75				CL																
	80	R	-30	100		SP	SAND, GRAVELLY SAND, SILTY SAND and CLAYEY SAND: brown, fine to coarse, poorly graded, dense to very dense															
						SC	SANDY GRAVEL, brown, fine, poorly graded, very dense, subangular to subrounded, medium to coarse sand.															
	67		-40			SP & GP	SANDY CLAY, yellow brown to red brown, stiff to hard, medium plastic, calcareous															
				140																		

SANDY CLAY, yellow brown to red brown,
stiff to hard, medium plastic, cal-
careous

CLAY, black to dark gray, very stiff
to hard, medium to highly plastic,
(Pierre Shale)

Total Depth 302 3' (92 1m)



140

160

180

200

220

240

260

280

300

320

50

60

70

80

90

67

95

83

83

89

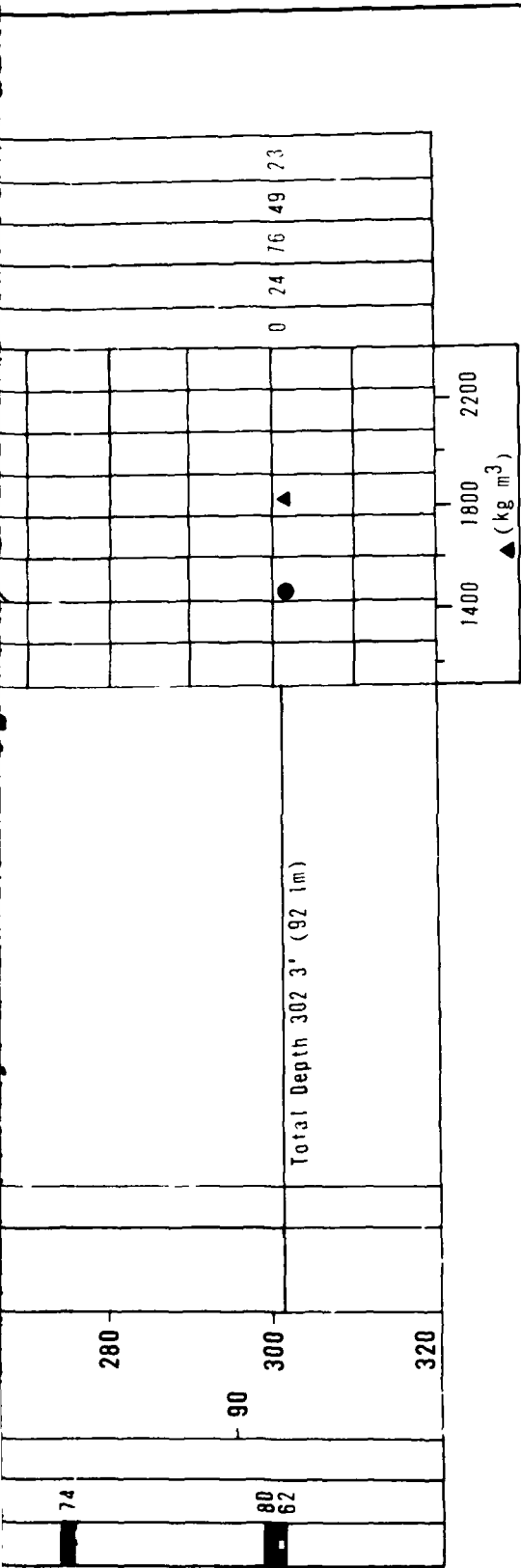
74

80
62

0 83 17

0 24 76 49 23

2



SAMPLE TYPES

□ STANDARD PENETRATION TEST

■ FUGRO DRIVE

□ BULK

■ PITCHER TUBE

▨ CORE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)

● - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 3225' (983m)
 DATE DRILLED : 7-9 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : 114' (34.7m)

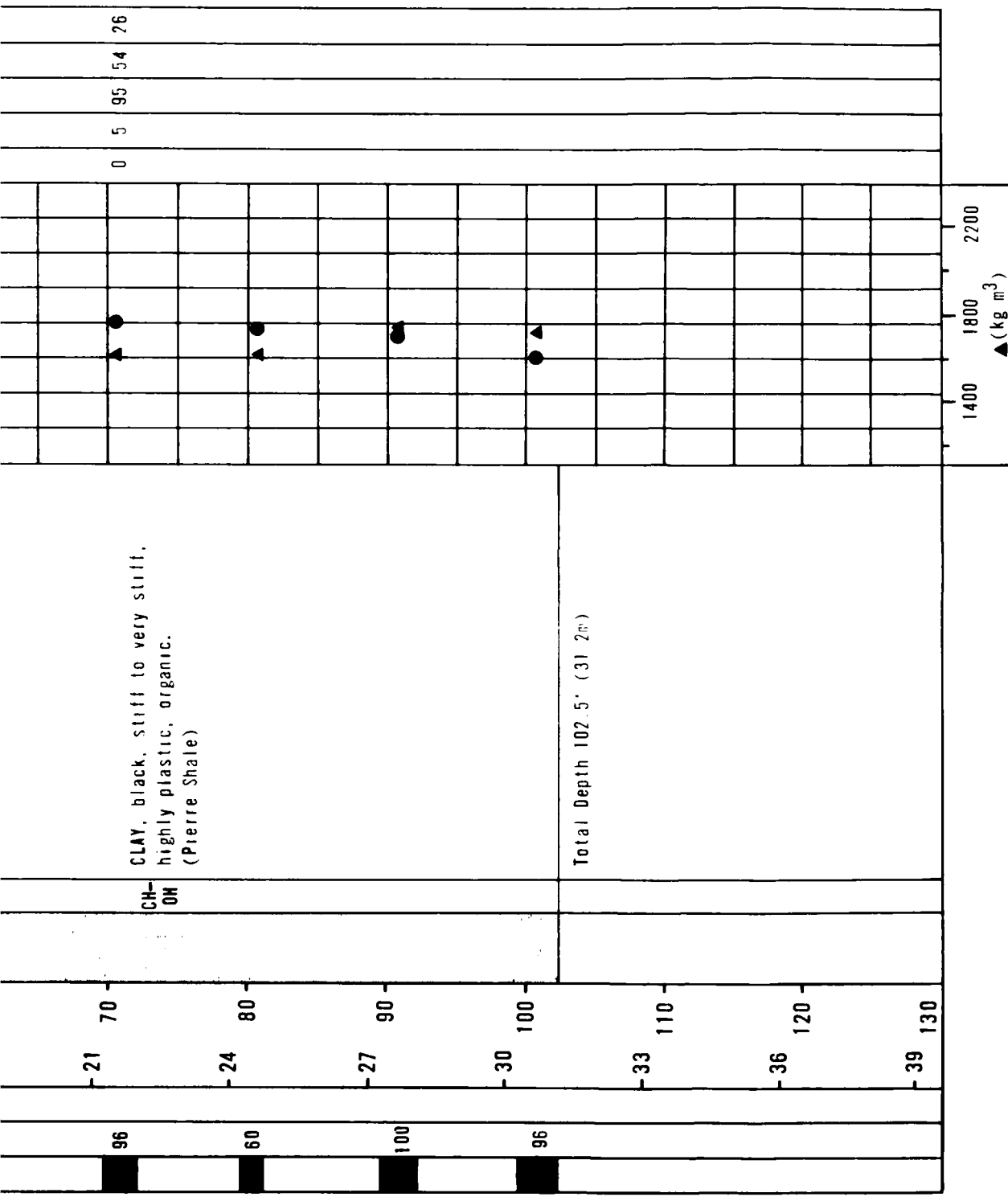
LOG OF BORING SY-B-6
 SCOTT CITY, KANSAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
 C-2

FUGRO NATIONAL, INC.

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION
	96		0	0		CL	
	92		-3	10		ML	CLAYEY SILT, light brown, firm, slightly plastic, calcareous; trace of fine sand; layer of dark brown, medium plastic silty clay (0-1.5').
	88						
	84		-6	20		SC	SILTY CLAY, light brown, stiff, slightly plastic, calcareous.
	86						
	68					CL- ML	CLAYEY SAND, brown and white, medium, poorly graded, medium dense, cal- careous.
	91		-9	30		CL	CLAYEY SILT and SILTY CLAY, brown and white, stiff, slightly to medium plastic, calcareous.
	80		-12	40		SP & GP	SAND and GRAVELLY SAND, fine to medium, poorly graded, very dense.
	86		-15	50		CH CL CH	CLAY, yellow brown to black, stiff to very stiff, highly plastic; layer of silty clay (46-47.5').
	86		-18	60			



SAMPLE TYPES

- ☐ STANDARD PENETRATION TEST
- ☒ FUGRO DRIVE
- ☐ BULK
- ☒ PLUTCHED TUBE

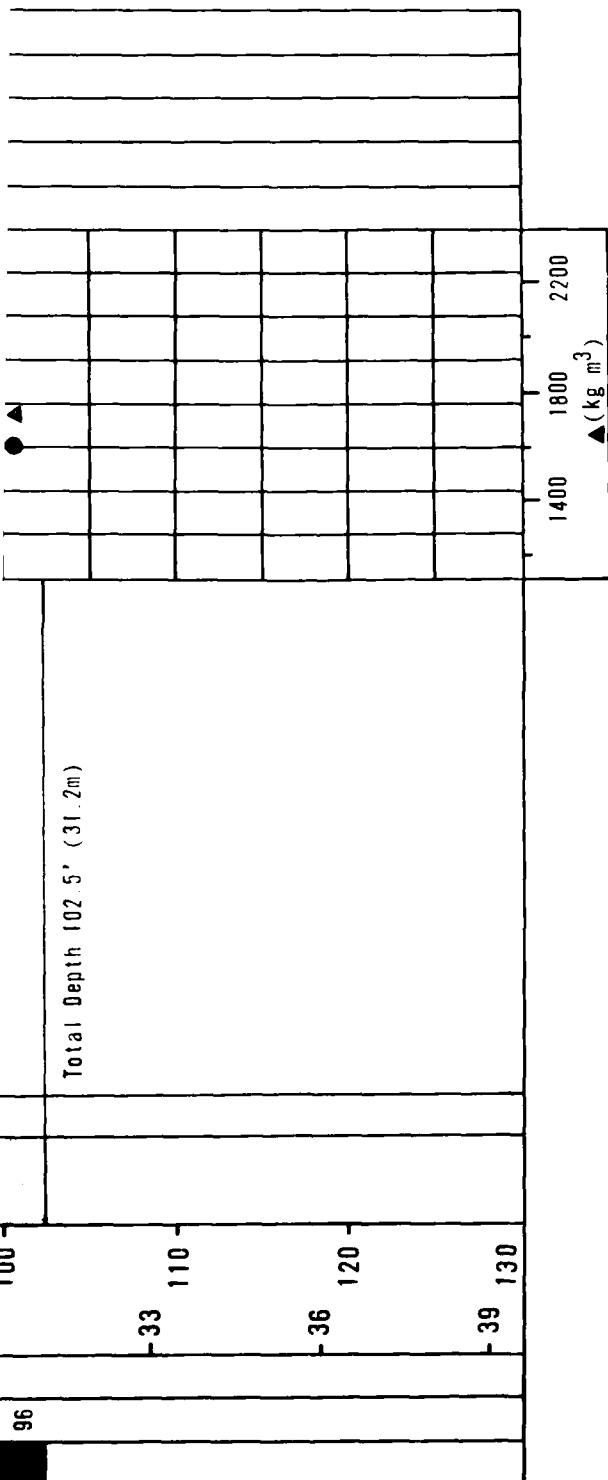
BORING DETAILS

ELEVATION : 2970' (905m)
 DATE DRILLED : 6-7 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None

LOG OF BORING
 SCOTT C
 CENTRAL HW

MX SITING INVE
 DEPARTMENT OF THE A

FUGRO NA



BORING DETAILS

ELEVATION : 2970' (905m)
 DATE DRILLED : 6-7 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Apparent

SAMPLE TYPES

☐ STANDARD PENETRATION TEST

☐ FUGRO DRIVE

☐ BULK

☐ PITCHER TUBE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
 R - N VALUE GREATER THAN 100 BLOWS/FOOT
 ▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
 ● - MOISTURE CONTENT (ASTM: D-2216-71)
 NR - NO RECOVERY

LOG OF BORING SY-B-11
 SCOTT CITY, KANSAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
 C-3

FUGRO NATIONAL, INC.

3

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		CL	Firm	SILTY CLAY, dark brown, slightly plastic, calcareous, moist.	0	1	99	45	21
	2										
	1			ML	Firm to stiff	SILT, light brown, non plastic, calcareous, slightly moist.					
	4										
	6										
	2										
	8										
	3	10									
	12										
	4										
	14										
	5	16									
	18										
	6	20									
	22										
						Total Depth 14.1' (4.3m) Stability of Vertical Walls: Stable 0-14.1' (4.3m)					

TRENCH DETAILS

SURFACE ELEVATION : 3225' (983m)
 DATE EXCAVATED : 7 October 1977
 SURFACE GEOLOGIC UNIT : A3L
 TRENCH LENGTH : 22' (6.7m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH SY-T-7 SCOTT CITY, KANSAS CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
 C-4

UGRO NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0	[Hatched Pattern]	CL-ML	Firm	SILTY CLAY, CLAYEY SILT, dark brown, slightly to medium plastic, calcareous, moist.					
	2									35	11
	1		[Dotted Pattern]	ML	Firm to stiff	SILT, light brown, slightly plastic, calcareous, slightly moist.					
	4										
	6										
	8										
	2						0	2	98	30	4
	10										
	12										
	4					Total Depth 12.0' (3.7m)					
	14					Stability of Vertical Walls:					
						Stable 0-12.0' (3.7m)					
	18										
	5										
	18										
	6										
	20										
	22										

TRENCH DETAILS



SURFACE ELEVATION : 3055' (931m)
 DATE EXCAVATED : 7 October 1977
 SURFACE GEOLOGIC UNIT : A3L
 TRENCH LENGTH : 22' (6.7m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH SY-T-8
 SCOTT CITY, KANSAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
 C-5

FUGRO NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		CL		SILTY CLAY, dark brown, slightly plastic, calcareous, slightly moist, trace of fine sand.					
	2										
	1			ML	Firm						
	4										
	6										
	8										
	2				Stiff						
	10										
	12										
	14										
	4					Total Depth 13.0' (4.0m) Stability of Vertical Walls: Stable 0-13.0' (4.0m)					
	16										
	18										
	20										
	6										
	22										

TRENCH DETAILS

SURFACE ELEVATION : 3372' (1028m)
 DATE EXCAVATED : 8 October 1977
 SURFACE GEOLOGIC UNIT : A3L
 TRENCH LENGTH : 23' (7.0m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH SY-T-13
 SCOTT CITY, KANSAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
 C-6

FUGRO NATIONAL, INC.

NOTES:

(c) **USCS - Unified Soil Classification System**

* Indicates that test has been performed and results are included in this report.

* Indicates that test has been performed and results are included in this report.

* Indicates that test has been performed and results are included in this report.

* Indicates that test has been performed and results are included in this report.

* Indicates that test has been performed and results are included in this report.

STANDARD SIEVE NO.					PARTICLE SIZE (mm)		ATTERBERG LIMITS (b)			USCS (c)	IN-SITU				COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL	UNCONFINED COMPRESSION	DIRECT SHEAR
											DRY UNIT WEIGHT		MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY					
40	100	200	.005	.001	LL	PL	PI	(pcf)	(kg/m³)		(pcf)	(kg/m³)				(pcf)	(kg/m³)				
								CL-ML	80.4	1288	13.4	33.1	1.01								
								ML	77.1	1235	9.9	22.5	1.18								
	100	98	2	2	29	23	6	ML	70.5	1129	14.2	27.7	1.39					*			
								ML	75.4	1208	25.9	56.8	1.24						*		
								ML	69.5	1113	28.1	53.3	1.42								
98	98	97	23	12	40	21	19	CL	82.4	1314	32.1	82.9	1.04				2.62				
								CL	93.8	1503	23.1	78.4	0.80								
76	23	17						SM	119.7	1917	14.5	95.0	0.41								
								CH	96.8	1551	25.3	92.3	0.74								
								CH	103.4	1656	18.9	81.1	0.63						*		
								CH	110.8	1775	15.2	78.9	0.52								
								CH	112.5	1802	14.6	79.5	0.50								
1	79	76	20	13	49	26	23	CL-CH	114.9	1841	12.7	72.8	0.47								

2

SUMMARY OF LABORATORY TESTS
BORING
SCOTT CITY, KANSAS, CE
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE
FUGRO NATIONAL

SUMMARY OF LABORATORY TEST RESULTS	
BORING SY-B-8	
SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMS0	TABLE C-1
FUGRO NATIONAL INC.	

3

[illegible]

SUMMARY OF UNCONFINED COMPRESSION TEST RESULTS

SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS

TABLE
C-2

FUGRO NATIONAL, INC.

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
C-3**FUGRO NATIONAL, INC.**[illegible]

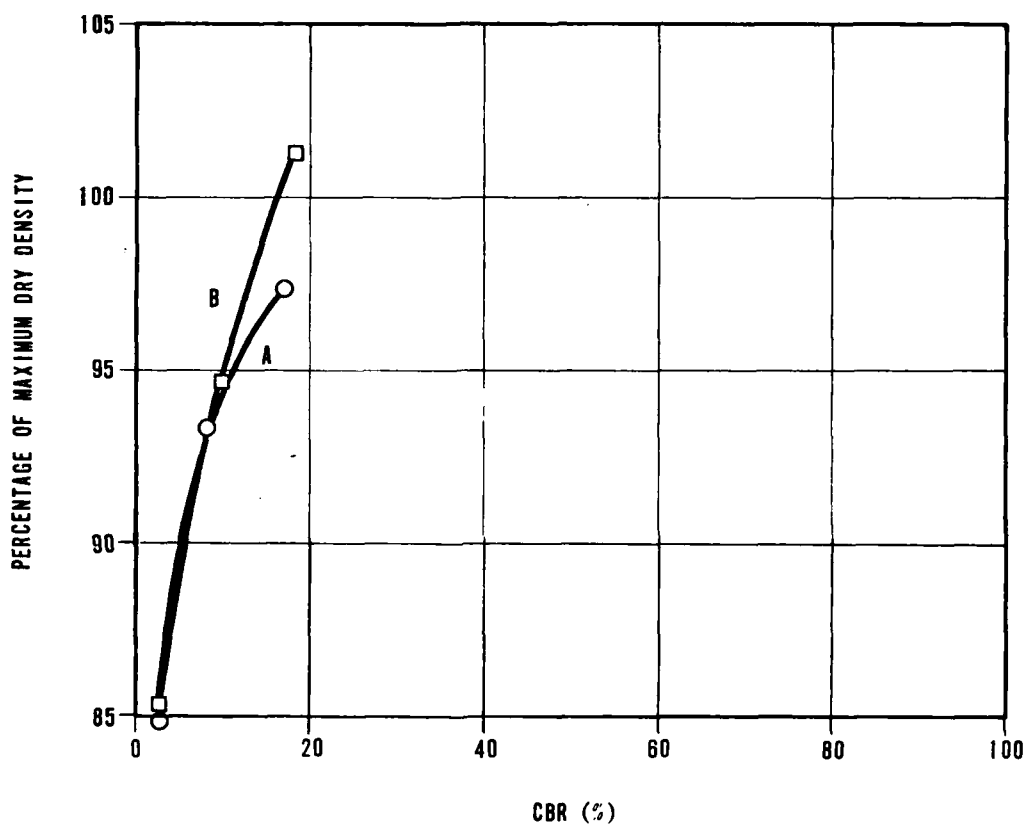
SUMMARY OF DIRECT SHEAR TEST RESULTS
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	SAMSO	TABLE C-4
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FUGRO NATIONAL, INC.

**TABLE
C-5**

FUGRO NATIONAL, INC.



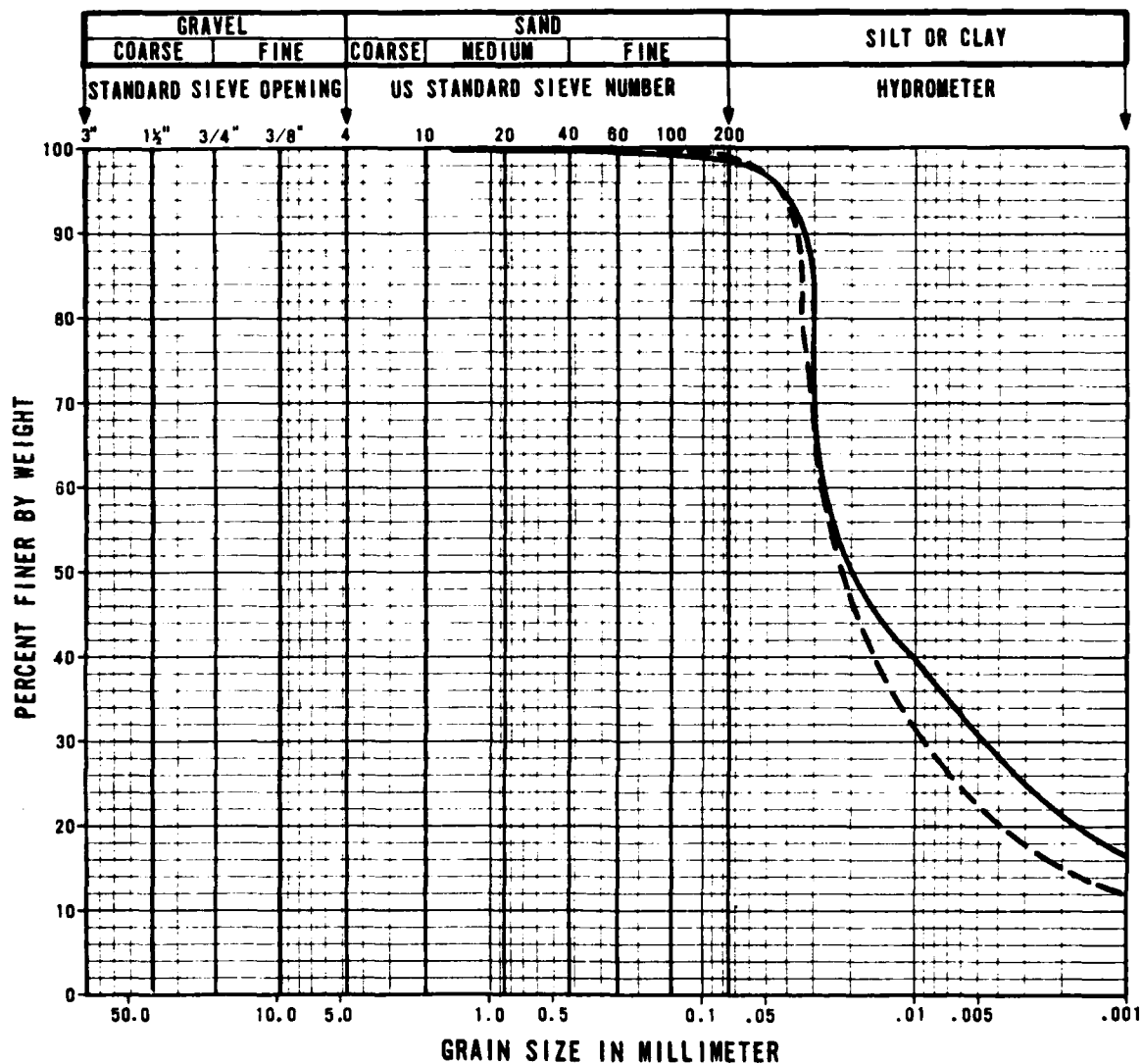
SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	CL-ML
□	B	ML

CALIFORNIA BEARING RATIO
(CBR) CURVES
SCOTT CITY, KANSAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
C-7

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	SY-T-7	0.5 - 1.5	0.15 - 0.46	CL-ML
		SY-T-8	1.0 - 2.0	0.31 - 0.61	
		SY-T-10	1.0 - 2.5	0.31 - 0.76	
---	B	SY-T-8	5.0 - 8.0	1.52 - 2.44	ML
		SY-T-10	5.5 - 8.5	1.68 - 2.44	

GRAIN SIZE CURVES, CBR TESTS
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
C-8

FUGRO NATIONAL, INC.

[illegible]

SUMMARY OF CHEMICAL TEST RESULTS
SCOTT CITY, KANSAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE
C-6**FUGRO NATIONAL, INC.**

APPENDIX D
GEOTECHNICAL DATA - CIMARRON

TABLE OF CONTENTS
APPENDIX D

BORING AND TRENCH LOGS

LOG OF BORING CN-B-2	Figure D-1
LOG OF BORING CN-B-5	Figure D-2
LOG OF BORING CN-B-6	Figure D-3
LOG OF TRENCH CN-T-3	Figure D-4
LOG OF TRENCH CN-T-8	Figure D-5
LOG OF TRENCH CN-T-17	Figure D-6

SUMMARY OF LABORATORY TEST RESULTS

BORING CN-B-5	Table D-1
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SUMMARY OF SHEAR STRENGTH TESTS

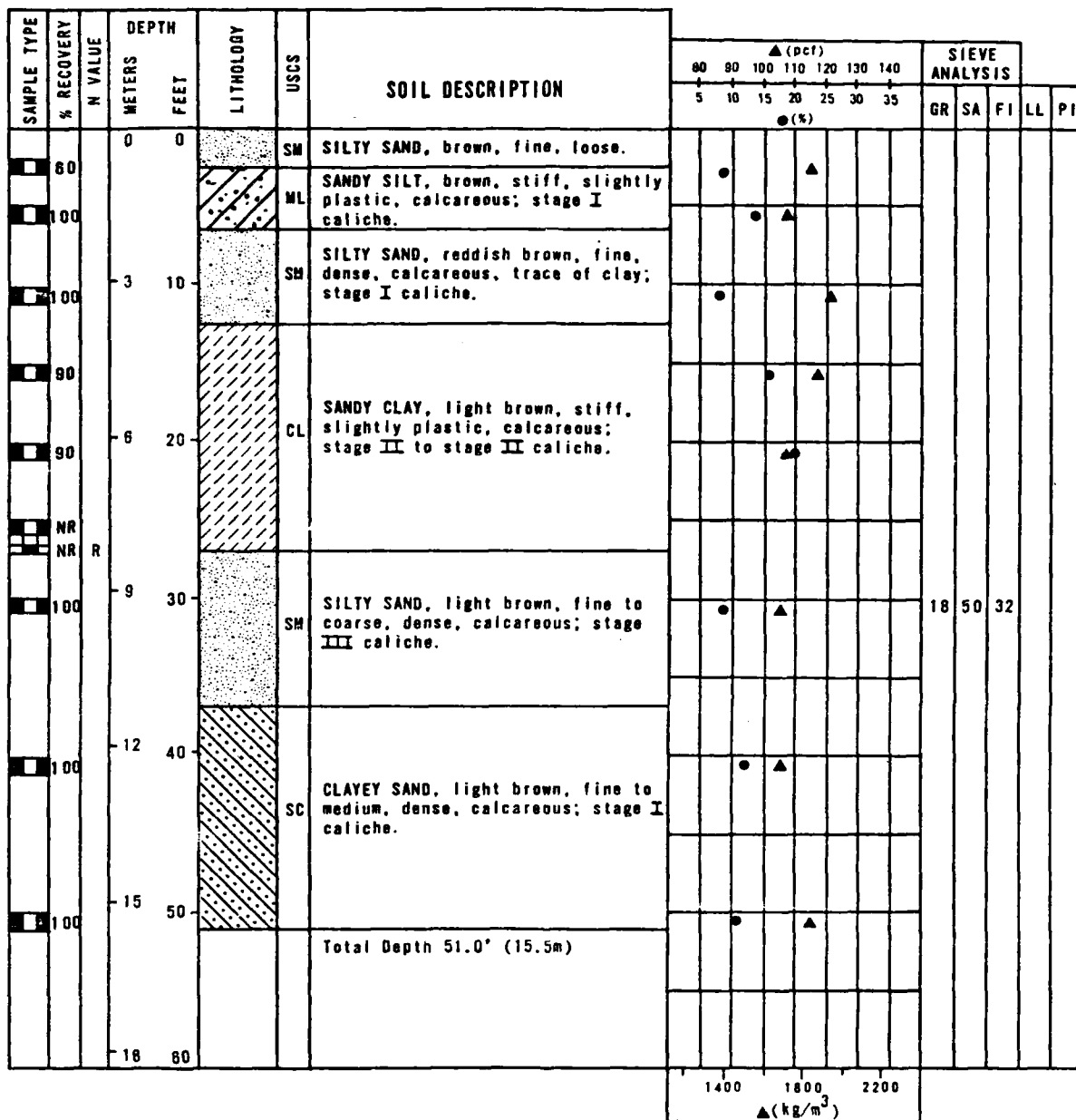
UNCONFINED COMPRESSION TEST RESULTS	Table D-2
TRIAXIAL SHEAR TEST RESULTS	Table D-3
DIRECT SHEAR TEST RESULTS	Table D-4

SUMMARY OF CALIFORNIA BEARING RATIO (CBR) TESTS

CALIFORNIA BEARING RATIO (CBR) TEST RESULTS	Table D-5
CALIFORNIA BEARING RATIO (CBR) CURVES	Figure D-7
GRAIN SIZE CURVES, CBR TESTS	Figure D-8

SUMMARY OF CHEMICAL TEST RESULTS

Table D-6



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

- N — STANDARD PENETRATION TEST (ASTM: D-1586-67)
- R — N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
- — MOISTURE CONTENT (ASTM: D-2216-71)
- NR — NO RECOVERY

BORING DETAILS

ELEVATION : 4025' (1227m)
 DATE DRILLED : 20 October 1977
 DRILLING METHOD : Hollow Stem Auger
 HOLE DIAMETER : 8 5/8" (188mm)
 CASING INSTALLED: None
 WATER LEVEL : Not Encountered

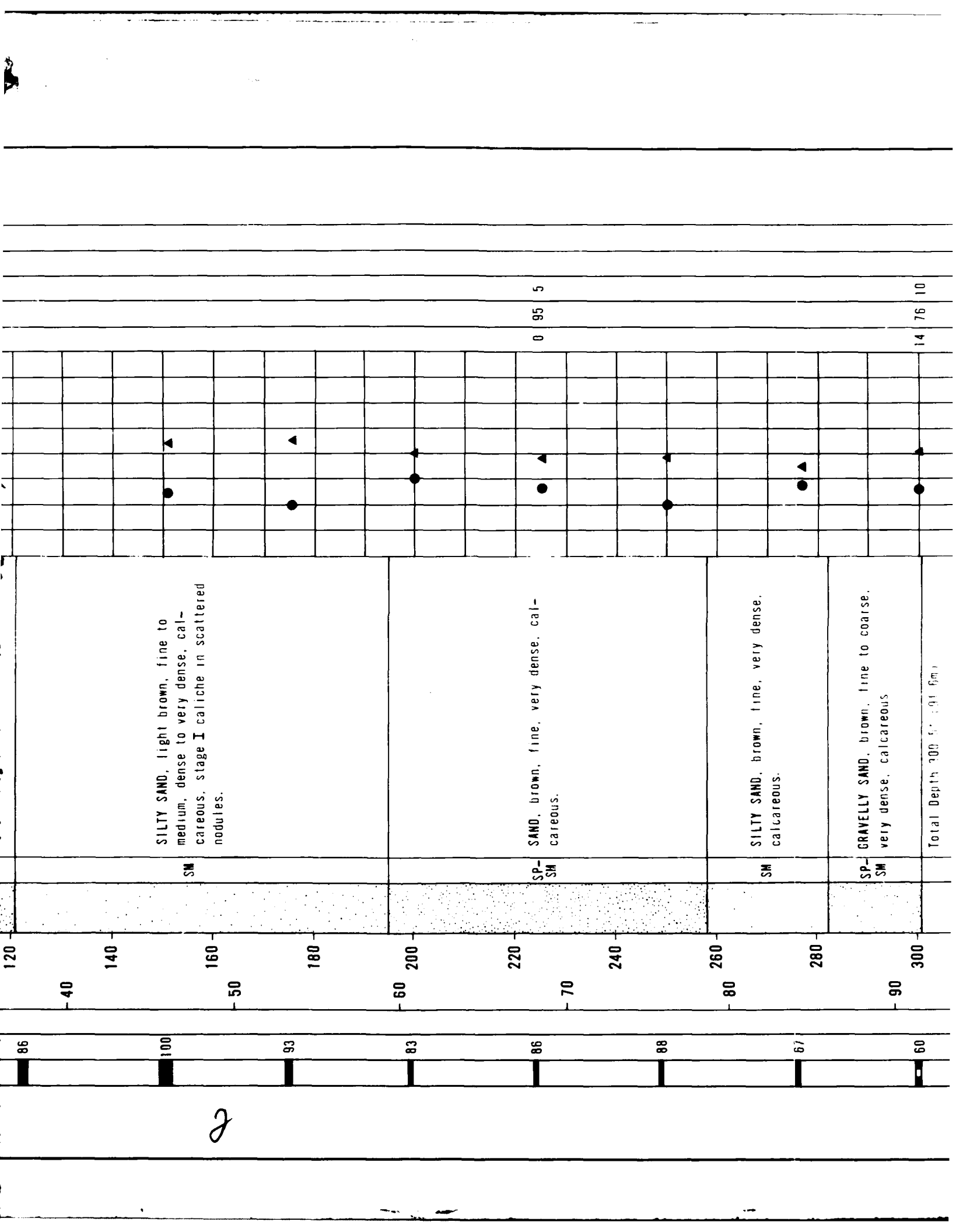
LOG OF BORING CN-B-2 CIMARRON, TEXAS CENTRAL HIGH PLAINS CSP

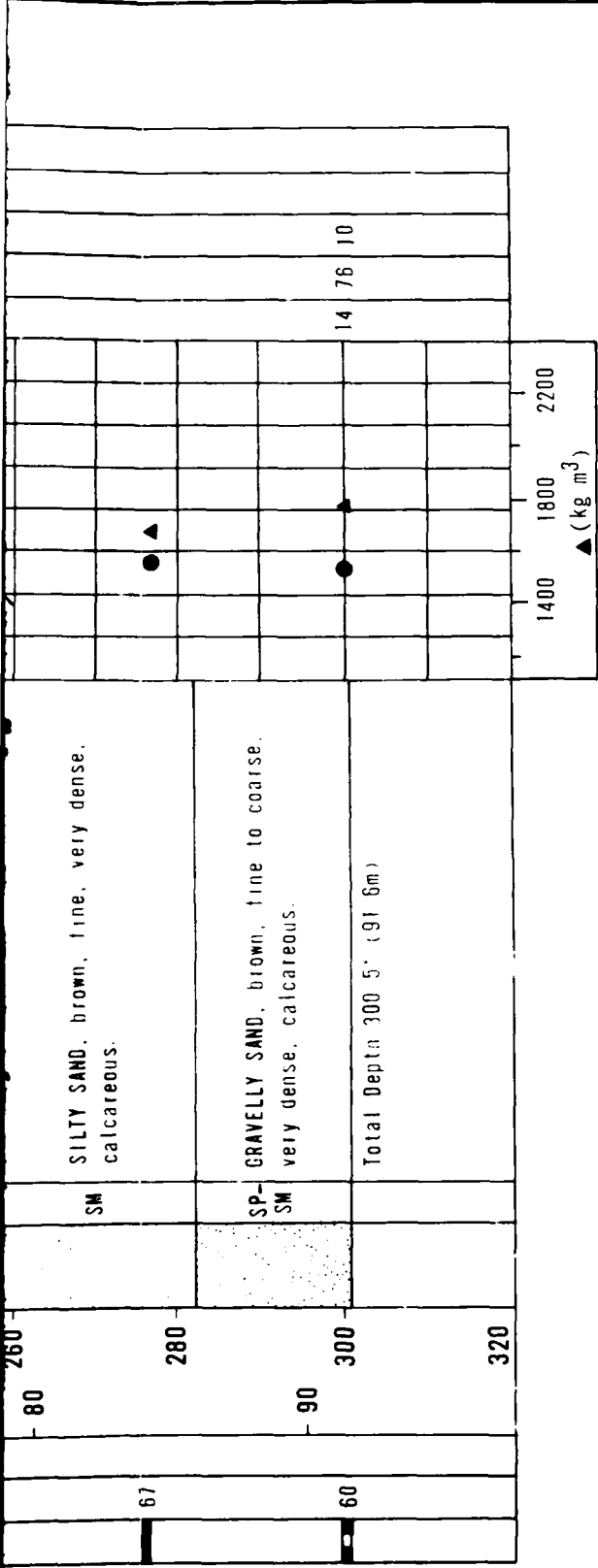
MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
 D-1

FUGRO NATIONAL, INC.

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION
	84		0	0	SC		CLAYEY SAND, reddish brown, fine, medium dense, calcareous, stage I to stage II caliche
	72				SP		
	80						
	100			20			SAND, white, medium to coarse, very dense, calcareous, stage III caliche.
	100						
	96						
	100		-10				
	100			40	SM		SILTY SAND, reddish brown, fine, medium dense, calcareous, stage I to stage II caliche.
	100						
	93		-20				
	83			60			
	50			80	GP		SANDY GRAVEL, brownish white, fine to coarse, dense, subrounded, fine to medium sand.
	80						
	100		-30	100	SP-SM		SAND, light brown, fine to medium, poorly graded, very dense, calcareous.
				120			
	86		-40				





SAMPLE TYPES

- ☐ STANDARD PENETRATION TEST
- ☐ FUGRO DRIVE
- ☐ BULK
- ☐ PITCHER TUBE
- ☐ CORE

ENGINEERING PARAMETERS

- N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
- R - N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
- - MOISTURE CONTENT (ASTM: D-2216-71)
- NR - NO RECOVERY

BORING DETAILS

ELEVATION : 4107' (1252m)
 DATE DRILLED : 18-20 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

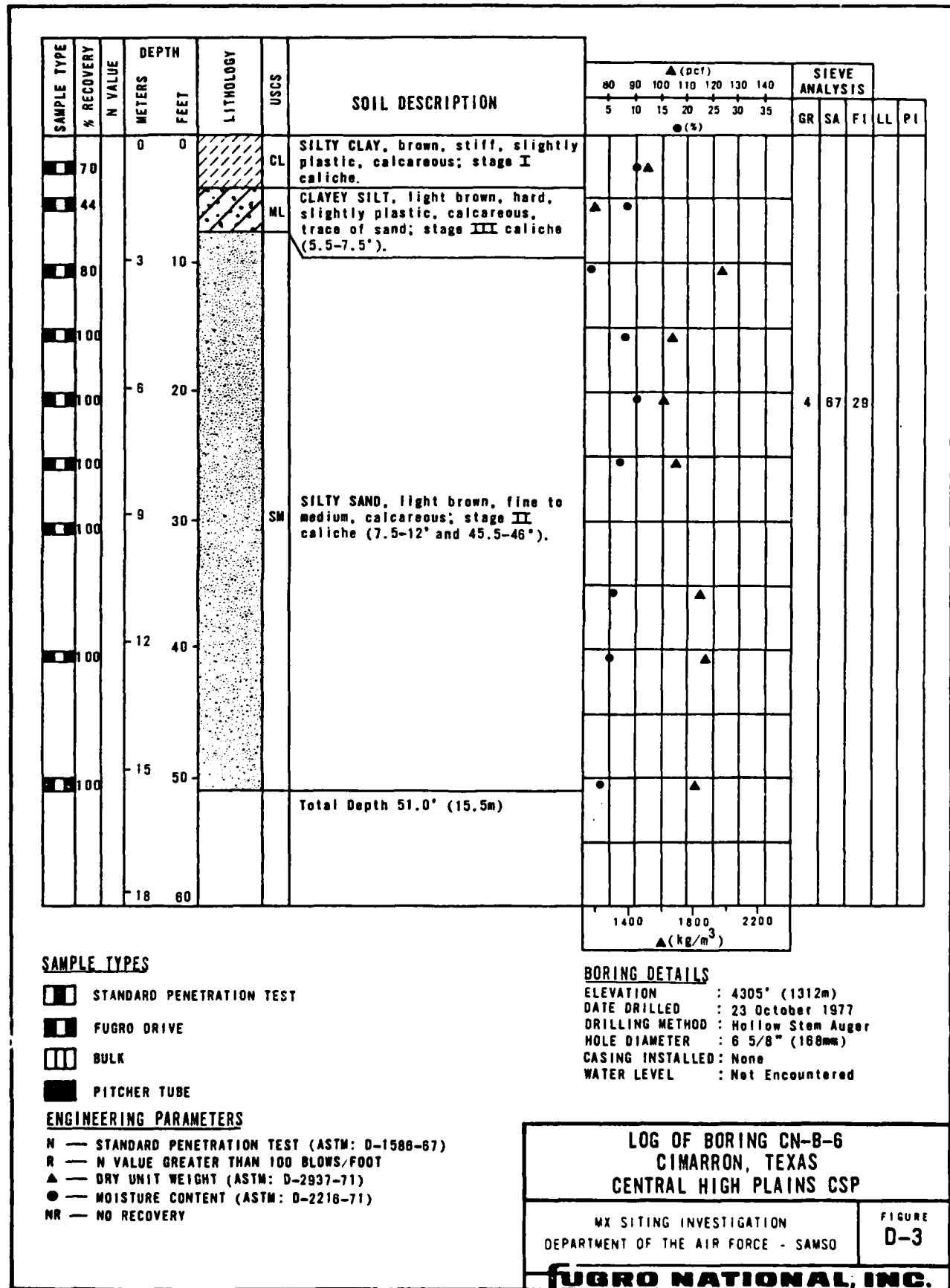
LOG OF BORING CN-B-5
 CIMARRON, TEXAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SANSO

FIGURE
 D-2

FUGRO NATIONAL, INC.

3



BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		SP	Loose	SAND, gray, fine, poorly graded, calcareous, dry, scattered caliche nodules.					
				SM	Medium dense	SILTY SAND, brown, fine to medium, poorly graded, calcareous, dry, weakly cemented, scattered caliche nodules.					
	2										
	1			CL	Hard	SANDY CLAY, brown, slightly plastic, calcareous, slightly moist, weakly cemented, slickensided.					
	4										
	6			ML	Very stiff	SANDY SILT, yellow brown, slightly plastic, calcareous, dry, moderately cemented; stage II caliche.					
	2										
	8			CL	Hard	SANDY CLAY, brown, slightly plastic, calcareous, dry, strongly cemented; stage II caliche.					
	3	10				Total Depth 9.4' (2.9m)					
						Stability of Vertical Walls: Stable 0-9.4' (2.9m)					
	12										
	4										
	14										
	5	16									
	18										
	6	20									
	22										

TRENCH DETAILS

SURFACE ELEVATION : 3987' (1209m)
 DATE EXCAVATED : 20 October 1977
 SURFACE GEOLOGIC UNIT : A3u
 TRENCH LENGTH : 25' (7.6m)
 TRENCH ORIENTATION : NS

LOG OF TRENCH CN-T-3
 CIMARRON, TEXAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
 D-4

FUGRO NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		SM	Loose	SILTY SAND, light brown, fine, poorly graded, dry.					
		2		CL	Stiff	SANDY CLAY, red, slightly plastic, calcareous, slightly moist, weakly cemented; stage I caliche with scattered nodules.					
	1	4		SC	Dense	CLAYEY SAND, red, fine, poorly graded, calcareous, slightly moist, weakly cemented; stage III caliche (7-7.5'), fractured stage IV caliche (below 7.5').					
	2	6									
	3	10				Total Depth 7.7' (2.3m) Stability of Vertical Walls: Stable 0-7.7' (2.3m) Cementation at 7.7' (2.3m) exceeded capacity of Case 580C backhoe					
	4	12									
	5	14									
	6	16									
		18									
		20									
		22									

TRENCH DETAILS

SURFACE ELEVATION : 4107' (1252m)
 DATE EXCAVATED : 22 October 1977
 SURFACE GEOLOGIC UNIT : A3u
 TRENCH LENGTH : 21' (6.4m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH CN-T-8 CIMARRON, TEXAS CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
 D-5

LOGS NATIONAL, INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		SC	Dense	CLAYEY SAND, brown, fine, poorly graded, calcareous, dry; stage I caliche.					
	2										
	1			CL	Very stiff	SILTY CLAY, red brown, slightly plastic, calcareous, slightly moist, trace of fine sand; stage II caliche.				32	16
	4										
	6										
	8										
	10										
	12										
	14										
	16										
	18										
	20										
	22					Total Depth 11.2' (3.4m) Stability of Vertical Walls: Stable 0-11.2' (3.4m)					

TRENCH DETAILS

SURFACE ELEVATION : 4043' (1232m)
 DATE EXCAVATED : 26 October 1977
 SURFACE GEOLOGIC UNIT : A3u
 TRENCH LENGTH : 23' (7.0m)
 TRENCH ORIENTATION : EW

LOG OF TRENCH CN-T-17
 CIMARRON, TEXAS
 CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
 D-6

FUGRO NATIONAL, INC.

NOTES:

(c) USCS - Unified Soil Classification System

P - Pitcher

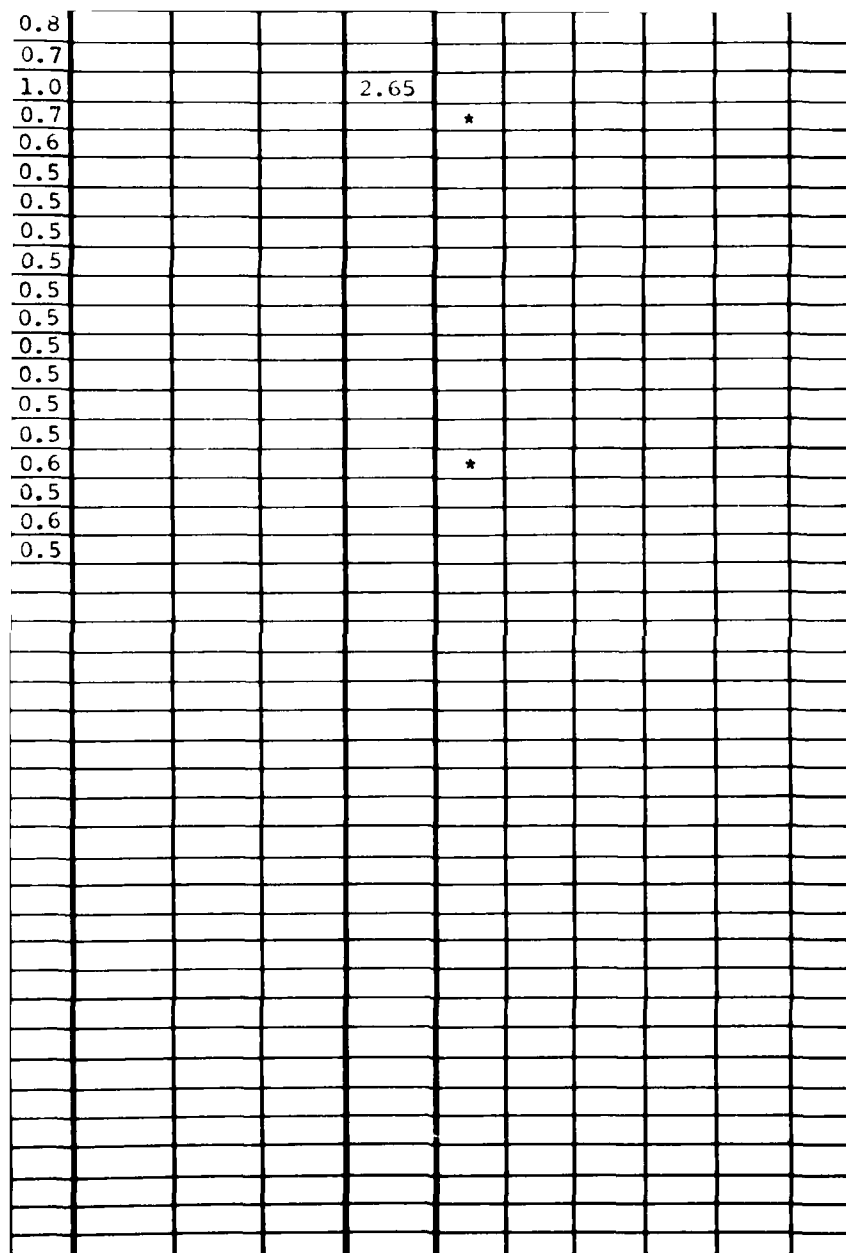
* Indicates that test has been performed and results are included in this report.

B - Bulk

(b) NP - Not Plastic

STANDARD SIEVE NO					PARTICLE SIZE (mm)		ATTERBERG LIMITS (b)			USCS (c)	IN-SITU					COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL	UNCONFINED COMPRESSION	DIRECT SHEAR	
AND			SILT OR CLAY		LL	PL	PI	DRY UNIT WEIGHT			MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)							
40	100	200	.005	.001				(pcf)	(kg/m ³)					(pcf)	(kg. m ³)		(pcf)	(kg. m ³)					
									SC	93.0	1490	9.1	30.2	0.8									
									SC	98.9	1584	9.2	35.4	0.7									
82	60	44	9	7					SM	86.1	1379	25.6	72.4	1.0				2.65					
									SM	100.9	1616	18.4	74.2	0.7					*				
									SM	103.4	1656	10.1	43.3	0.6									
									SM	110.8	1775	9.2	47.9	0.5									
									SM	109.3	1751	10.7	53.6	0.5									
									SM	110.4	1768	8.9	45.9	0.5									
									SM	112.9	1808	7.4	40.6	0.5									
									SM	111.8	1791	7.0	37.5	0.5									
									SP	114.5	1834	5.2	29.5	0.5									
62	12	8							SP	113.1	1812	11.3	62.4	0.5									
									SM	114.0	1826	12.6	71.1	0.5									
									SM	115.1	1844	10.5	62.5	0.5									
									SP-SM	111.8	1791	15.7	83.7	0.5									
92	14	5							SP-SM	108.9	1744	13.8	66.1	0.6					*				
									SP-SM	109.6	1756	11.3	56.9	0.5									
									SM	107.4	1720	14.2	67.5	0.6									
79	21	10							SP-SM	111.7	1789	13.3	70.6	0.5									

2



**TABLE
D-2**

FUGRO NATIONAL, INC.

[illegible]

SUMMARY OF TRIAXIAL SHEAR TEST RESULTS
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

**TABLE
D-3**

FUGRO NATIONAL, INC.

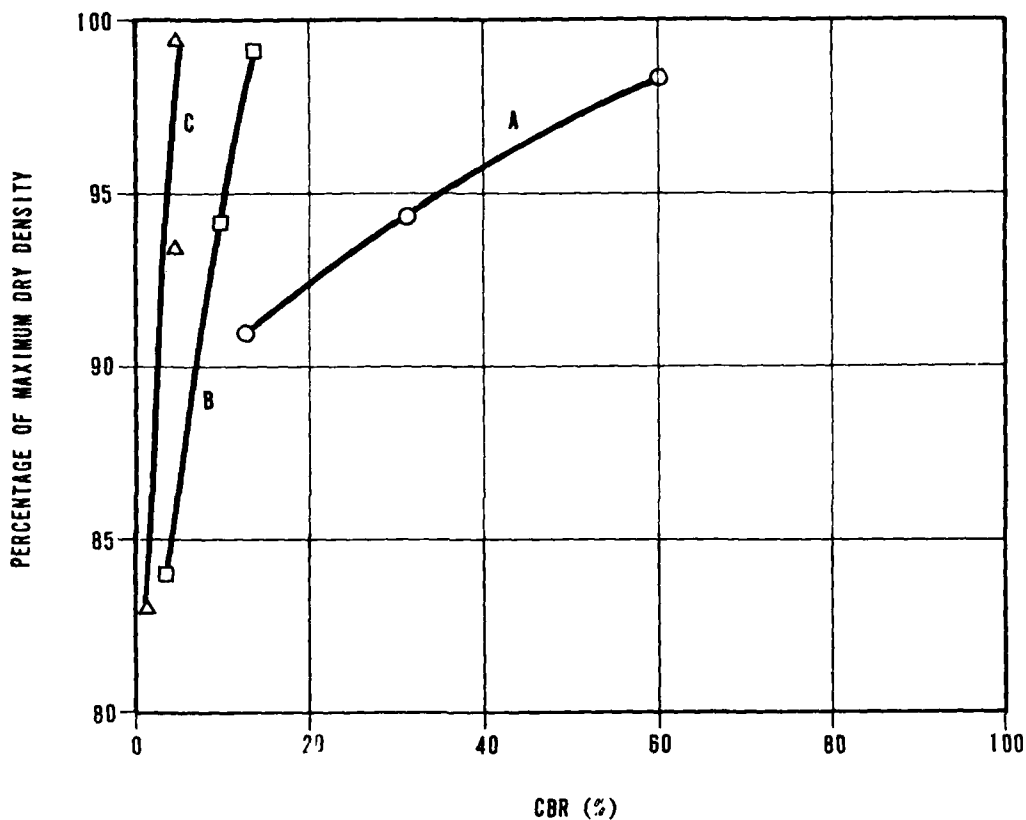
COMPOSITE SAMPLE NUMBER	SOIL TYPE	PERCENT PASSING #200	ATTERBERG LIMITS		SPECIFIC GRAVITY	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)	COMPACTED DRY DENSITY		COMPACTED MOISTURE (%)	PERCENT OF MAXIMUM DRY DENSITY	CBR (%)
			LL	PI		pcf	kg/m ³		pcf	kg/m ³			
A	SM	14			2.62	121.0	1938	9.5	118.8	1803	9.3	98.2	60
									114.1	1828	9.4	94.3	31
									110.2	1765	9.3	91.1	13
B	CL	68	29	14	2.64	122.0	1954	12.7	120.9	1937	12.2	99.1	14
									114.9	1841	12.7	94.2	10
									102.5	1642	12.4	84.0	4
C	CL	75	37	19	2.58	116.0	1858	14.5	115.3	1847	13.0	99.4	5
									108.4	1737	13.7	93.4	5
									96.3	1543	13.5	83.0	2

CALIFORNIA BEARING RATIO
(CBR) TEST RESULTS
CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
D-5

FUGRO NATIONAL, INC.



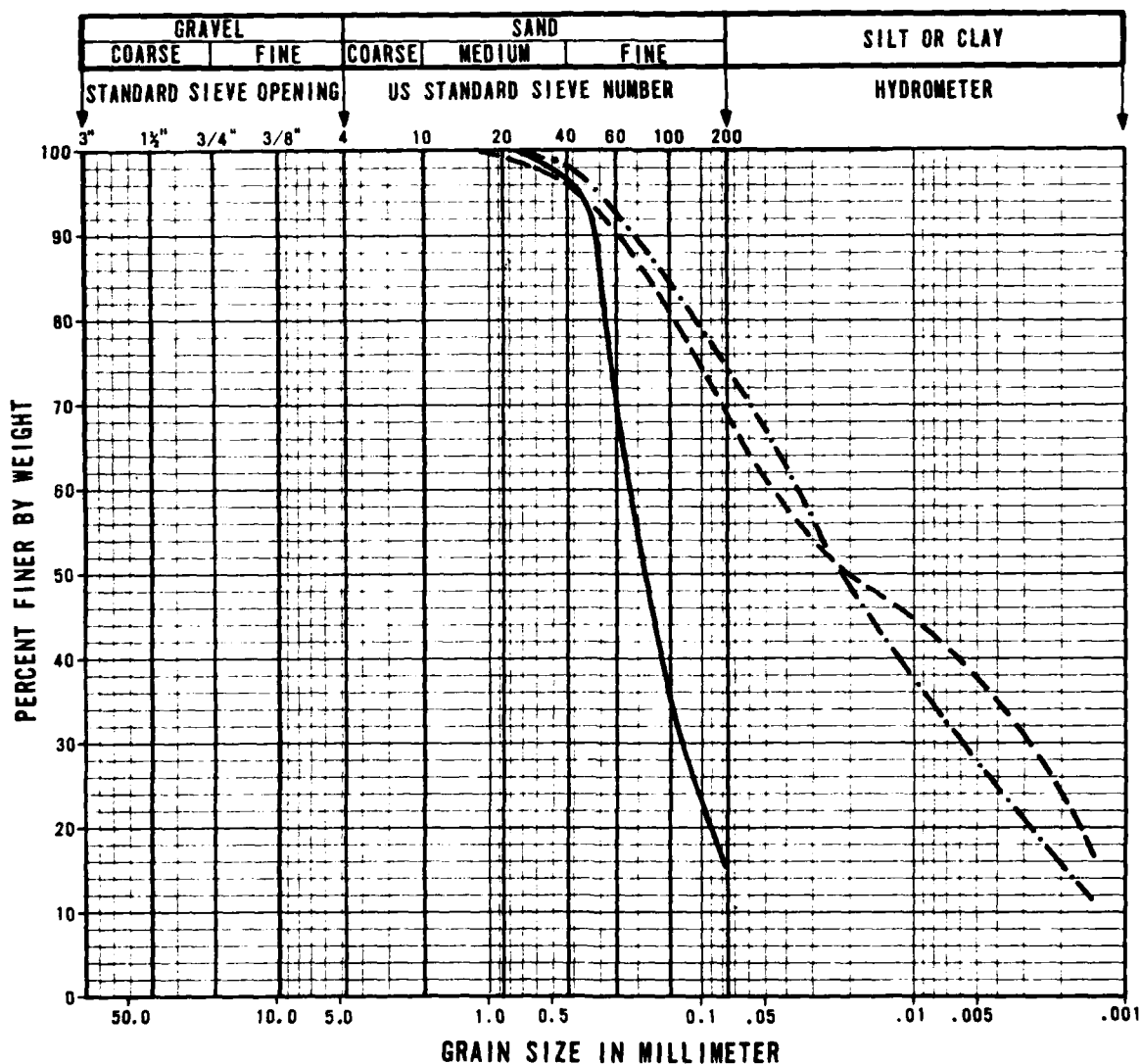
SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SM
□	B	CL
△	C	CL

CALIFORNIA BEARING RATIO
(CBR) CURVES
CIMARRON, TEXAS, CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
D-7

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	CN-T-11	0.5 - 1.5	0.15 - 0.46	SM
		CN-T-12	0.5 - 1.4	0.15 - 0.43	
---	B	CN-T-5	0.5 - 1.5	0.15 - 0.46	CL
		CN-T-6	2.0 - 3.0	0.61 - 0.91	
		CN-T-18	1.3 - 2.0	0.40 - 0.61	
-.-	C	CN-T-9	1.5 - 2.5	0.46 - 0.76	CL
		CN-T-13	1.5 - 3.0	0.46 - 0.91	

GRAIN SIZE CURVES, CBR TESTS
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS

FIGURE
D-8

FUGRO NATIONAL, INC.

[illegible]

SUMMARY OF CHEMICAL TEST RESULTS
CIMARRON, TEXAS
CENTRAL HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS0

TABLE 1

UGRO NATIONAL, INC.

END

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